



EARLY MIDDLE CAMBRIAN TRILOBITES FROM LA LAJA FORMATION, CERRO EL MOLLE, PRECORDILLERA OF WESTERN ARGENTINA

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ABSTRACT—A tectonically undeformed portion of the lower part of La Laja Formation is exposed at Cerro El Molle near San Juan, Precordillera of western Argentina. It consists of shallow-water, variably argillaceous lime mudstone and sporadically interbedded bioclastic grainstone deposited in an inner shelf setting. The El Estero Member and the basal 0.2 m of the Soldano Member contain a trilobite fauna of olenelloids and ‘simple’ ptychoparioids indicative of the early Cambrian (series 2, stage 4; Dyeran stage of Laurentia). The succeeding 50 m of the lower Soldano Member yield trilobites characteristic of the early middle Cambrian (series 3, stage 5; Delamarian stage of Laurentia). In ascending order of occurrence, *Amecephalus arjosensis*, *Kochiella maxeyi* and *Eokochaspis nodosa*, along with several other taxa, including *Ptychobaba* n. gen. (type species *Ptychoparella buttsi*), belong to the traditional lower *Plagiura–Poliella* Biozone. However, while this fauna is similar to that of the Great Basin, the nominative species of the *Eokochaspis nodosa* and overlying *Amecephalus arjosensis* biozones recognized in southern Nevada occur in reverse order in the Soldano Member. This suggests that the ranges of these species overlap, thereby reducing the temporal resolution in the Precordillera into a combined *Amecephalus arjosensis–Eokochaspis nodosa* Biozone. Argillaceous lime mudstones at the top yield *Mexicella mexicana*, indicative of the *Mexicella mexicana* Biozone recognized in the Great Basin, which is equivalent to the traditional *Albertella* Biozone of Laurentia. Because corynexochids are almost absent, the low-diversity ‘kochaspid’-dominated biofacies appears to typify the platform interior. The fauna is entirely Laurentian in composition, reinforcing notions of a close proximity of Cuyania to Laurentia during the Cambrian that enabled faunal migration and interchange. The absence of a late early Cambrian to early middle Cambrian hiatus correlative with the Hawke Bay Event, however, suggests no close affinity to the Iapetus-facing margin of eastern Laurentia.

INTRODUCTION

THE PRECORDILLERA of western Argentina is part of an allochthonous terrane that was emplaced against the South American portion of Gondwana in the late Ordovician (Thomas and Astini, 2003; Ramos, 2004; Voldman et al., 2008). Cuyania, as it has been called, is cored by a Cambro–Ordovician sedimentary succession that comprises the deposits of a now west-facing carbonate platform and adjacent slope (Keller, 1999; Bordonaro, 2003; Pratt et al., 2012). The Cambrian stratigraphic evolution of the Precordillera bears some similarities to that of southeastern U.S.A., which led to the proposal that the terrane represents a passive margin that rifted from some part of the Ouachita Embayment, a re-entrant in the continental margin facing Iapetus during the early Paleozoic (e.g., Dickerson and Keller, 1998; Thomas and Astini, 2003; Naipauer et al., 2010; Dickerson, 2012). Indeed, the general similarity in faunal composition between the Precordillera and Laurentia had long been noted for the Cambrian, although this similarity became progressively reduced through the Middle Ordovician, presumably due to continued drift and closer proximity to Gondwana (Benedetto et al., 1999). On the other hand, detrital zircon ages have been interpreted as evidence for a Gondwanan origin for the Precordillera, and the trilobite paleobiogeographic connection may have been due to dispersal via favorable ocean currents (Finney, 2007).

Cambrian trilobites occur sporadically in the autochthonous platform succession (Bordonaro et al., 2008, 2013), but more commonly in large limestone olistostroliths in Ordovician shales (e.g., Bordonaro and Fojo, 2011; Tortello, 2011) which represent blocks of fossiliferous upper slope facies (Bordonaro, 2003). While the Laurentian aspect of the trilobite faunas is

evident, relatively few species have been documented in sufficient detail to make firm biostratigraphic and biogeographic comparisons. The purpose of this paper is to describe the early middle Cambrian (series 3, stage 5; Delamarian stage of Laurentia) trilobite fauna in inner platform facies of the lower Soldano Member of La Laja Formation.

STRATIGRAPHY AND LOCALITY

La Laja Formation is the lowest unit in the Precordillera Oriental near the city of San Juan, and is exposed in a west-verging but east-dipping imbricated thrust slice forming the Sierra Chica de Zonda and the Sierra de Villicum (Fig. 1). It is subdivided in ascending order into El Estero, Soldano, Rivadavia and Juan Pobre members (Bordonaro, 2003), reflecting a stratigraphy composed of alternating units of inner-shelf, variably argillaceous limestones and clean, locally oolitic open-shelf facies (Pratt and Bordonaro, 2007; Gómez et al., 2007). The ocean lay generally to the west (Keller, 1999), and the trajectory from Quebrada de Zonda north-northeastwards to Cerro El Molle probably represents an obliquely shoreward trend (Pratt et al., 2012).

The formation reaches some 500 m in thickness, an estimate, however, because of thrust faulting and folding in El Estero and lower Soldano members. Exposed at Cerro El Molle on the southwestern side of Sierra de Villicum is a coherent, 80 m thick section covering the upper 30 m of El Estero Member and the lower 50 m of the Soldano Member (Figs. 2, 3). The base of the Soldano Member is marked by 0.2 m of bioclastic grainstone containing olenelloids, a species assigned to *Bonnia*, and a ‘simple’ ptychoparioid assigned to *Antagmus* (Bordonaro, 1986) representing the traditional latest early Cambrian (until formal

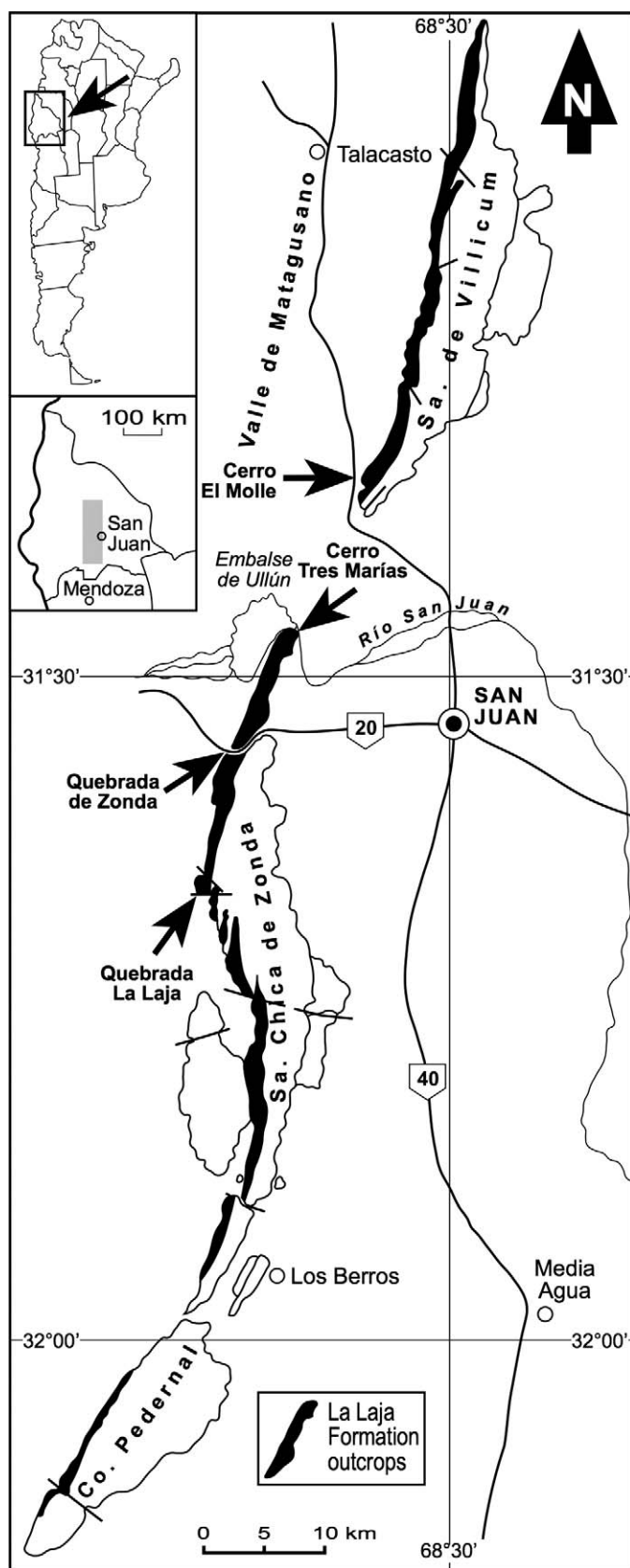


FIGURE 1—Location map of the study area in the Precordillera of western Argentina near San Juan. Outcrop of La Laja Formation in the Sierra de Chica de Zonda and Sierra de Villicum is colored black. Also shown are major faults offsetting the thrust sheets. The four localities of interest are Cerro El Molle, Cerro Tres Marias, Quebrada de Zonda, and Quebrada La Laja.

definition, taken here as equivalent to series 3, stage 4; Dyeran stage of Laurentia). This overlies 6 m of rubbly weathering argillaceous lime mudstone, below which are another ~25 m of thin-bedded lime mudstones and argillaceous lime mudstone, belonging to the upper El Estero Member. These also contain rare olenelloids and “*Antagmus*” sp. (Bordonaro, 1986), as well as the rhynchonelliform brachiopod *Diraphora* sp. (Benedetto and Foglia, 2012). Equivalent strata in Quebrada de Zonda contain a similar fauna (Borrello, 1963, 1964).

The basal grainstone is overlain sharply but conformably by 0.8 m of glauconitic bioclastic grainstone (Fig. 4.1) yielding the first trilobites of middle Cambrian (series 3, stage 5; Delameran stage of Laurentia) aspect. The lower Soldano Member consists of about 45 m of thinly interbedded, lime mudstones and locally sandy bioclastic grainstones, with a medium bed of thrombolites 12 m above base. This is overlain by about 5 m of mainly rubbly weathering argillaceous lime mudstone (Fig. 4.2) containing the youngest trilobite fauna described here, consisting primarily of *Mexicella mexicana*. Trilobite sclerites are usually fragmented in the grainstones, whereas in the argillaceous lime mudstones near at the top scarce whole cranidia are present. Above 50 m the Soldano Member is faulted and folded and a coherent stratigraphy cannot be assembled.

Foglia and Vaccari (2010; Benedetto and Foglia, 2012) presented a measured section of the same outcrop (which they referred to as both Cerro Molles and Cerro Molle). They placed the base of the Soldano Member ~23 m above their highest collection of olenelloids and *Bonnima* sp., and ~4 m below a horizon that yielded a single pygidium assigned to *Fieldaspis* sp. which they considered to mark the base of the Delamarian stage. The brachiopod *Wimanella mollensis* Benedetto and Foglia, 2012 comes from the same level. Unfortunately, their section cannot be reconciled against the section portrayed in Figure 2, such that where they placed contact between the Estero and Soldano members is probably not at the same stratigraphic level as recognized here. Because *W. mollensis* was reported from higher in the lower Soldano Member at Cerro Tres Marias, it is likely that Foglia and Vaccari (2010) placed the contact at Cerro El Molle ~15–20 m higher than we do.

PALEOECOLOGY

The lower Soldano Member was deposited in a shallow-water, low-energy, near-shore setting as suggested by the dominance of lime mudstone with variable argillaceous input. The sporadic bioclastic grainstones with fragmented (trilobite) and disarticulated (echinoderm) bioclasts indicate low-level wave-induced turbulence (Pratt and Bordonaro, 2007). Even though trilobites are generally not abundant they were part of the in situ fauna, and their occurrence represents episodes of benthic colonization, with occasional concentration of sclerites into grainstones. Phosphatic brachiopods are virtually absent. Recovery of protaspides and meraspides belonging to *Kochiella maxeyi* and *Amecephalus arjosensis* indicate that at least some of the trilobite species reproduced in this setting. However, these were collected from grainstones which provide a greater chance of discovery of these small elements. By contrast, sparse *Eokochaspis nodosa* and *Mexicella mexicana* were collected from fine-grained grainstones and lime mudstones respectively but no co-occurring early ontogenetic stages of these species were found. Their apparent absence is probably a preservational artefact.

Following the extinction of olenelloids, outer-shelf regions of Laurentia and Gondwana hosted a number of species belonging to Oryctocephalidae, along with various ptychoparioids (Sundberg and McCollum, 2003b). Beginning in *Albertella* Biozone

time, eodiscoids and agnostoids become common in open-shelf and slope deposits in Laurentia (Robison, 1976). None of these taxa is present in the lower Soldano Member. In the Great Basin, the inner-shelf biotas have been considered to comprise the *Albertella*–*Mexicella* Biofacies, whereas during the *Albertella* Biozone interval the platform-margin and slope counterparts are the *Zacanthoidid* and *Ogygopsis* biofacies respectively (Palmer and Campbell, 1976; Palmer and Halley, 1979). Although structural complications cast some doubt on the stratigraphic order of the faunas used to define the last two biofacies (McCullum and Sundberg, 2007), representatives of the *Zacanthoididae* and *Dolichometopidae* are essentially absent at Cerro El Molle. The presence of *Mexicella mexicana* at the top of the succession supports an inner-shelf setting which is consistent with the facies character.

The pre-*Albertella* Biozone trilobite fauna in the lower Soldano Member is dominated by ‘kochaspid’ species belonging to *Amecephalus*, *Kochiella* and *Eokochaspis*. These species also occur in other early middle Cambrian successions, especially in the southern Great Basin (Palmer and Halley, 1979; Eddy and McCollum, 1998; Sundberg and McCollum, 2002, 2003a, 2003b) and to some extent in the southern Rocky Mountains of western Canada (Rasetti, 1951, 1957). However, these units are characterized by more open-marine, mid- and outer-shelf carbonate or mixed carbonate–siliciclastic facies (Palmer and Halley, 1979; Aitken, 1997; McCollum and McCollum, 2011), in which zacanthoidids and dolichometopids are relatively common. As corynexochids are nearly absent in the lower Soldano Member, these strata appear to record the most landward platform setting. Consequently, it can be surmised that the ‘kochaspids’ found in La Laja Formation exhibited the broadest paleoenvironmental tolerance of trilobites in Laurentia during this time interval.

BIOSTRATIGRAPHY

The trilobites described herein come from the lower part of the traditional middle Cambrian whose base was taken by convention at the extinction of the olenelloids. For the sake of simplicity, we consider this boundary to be coincident with the base of provisional series 3, stage 5 even though it is not formalized as such. Palmer (1988) erected the Delamaran stage for this interval in Laurentia. This interval was subdivided into the traditional, generalized genus-based scheme consisting of the *Plagiura*–*Poliella*, *Albertella* and *Glossopleura* biozones, from oldest to youngest (e.g., Palmer and Halley, 1979; Taylor et al., 2012). Rasetti (1951) erected a biostratigraphy for open-shelf deposits at the platform margin in the southern Rocky Mountains of western Canada comprising the *Wenkchemnia*–*Stephenaspis*, *Plagiura*–*Kochaspis*, *Albertella* and *Glossopleura* biozones.

Sundberg and McCollum (2000, 2003a, 2003b; McCollum and Sundberg, 2007) developed a parallel, more refined biozonation for open-shelf versus restricted shelf settings in southern Nevada, with the *Eokochaspis nodosa* Biozone followed by the *Amecephalus arrojensis* Biozone common to both settings and equivalent to the lower part of the

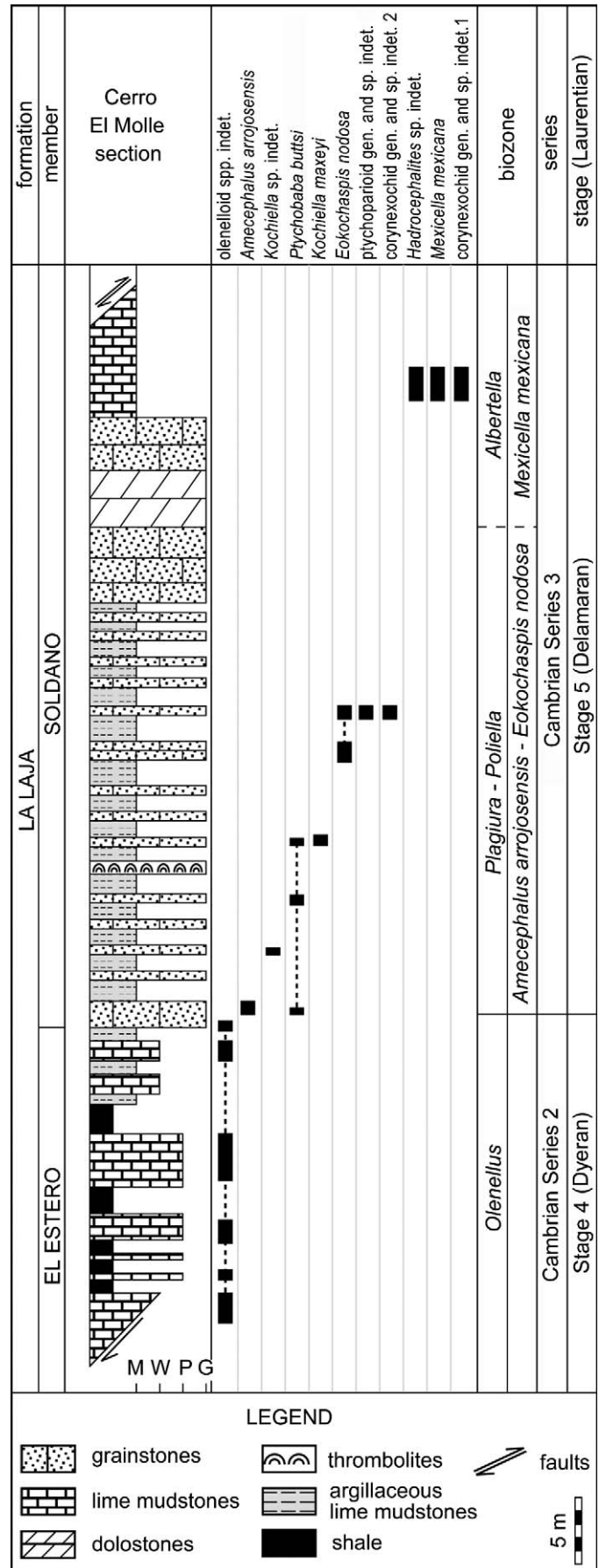


FIGURE 2—Measured section on Cerro El Molle at the southwestern flank of Sierra de Villicum, and stratigraphic distribution of trilobites. The section in Foglia and Vaccari (2010; Benedetto and Foglia, 2012) does not accord lithologically with ours. Also, because they place the contact between El Estero and Soldano members ~20 m above their highest olenelloid, it is probably higher than where we place it. For the sake of convenience provisional series 3, stage 5 is equated with the Laurentian Delamaran stage even though its base is not yet formalized.



FIGURE 3—Panorama facing east of uppermost El Estero and lower Soldano members, Cerro El Molle. Contact between El Estero and Soldano members is shown by white line at left (Fig. 4.1). The upper El Estero Member contains lower Cambrian olenelloids. Some 30 m stratigraphically below the contact as well as higher up the hillside El Estero member is faulted and folded. The top of the coherent section of the Soldano Member is at the vegetated skyline where *Mexicella mexicana* was collected (Fig. 4.2), above which the strata deformed. A small rotated fault-bounded lens (or fold) is present in the gully towards the right side of photograph, below the steep, light-colored hillside.

traditional *Plagiura–Poliella* Biozone. These are succeeded by the *Poliella denticulata*, *Mexicella mexicana* and *Glossopleura walcottii* biozones. The *Poliella denticulata* Biozone is equivalent to the upper *Plagiura–Poliella* Biozone of traditional usage, while the *Mexicella mexicana* Biozone is the restricted-shelf paleoenvironmental equivalent to the *Albertella* Biozone. In the open-shelf setting, the *Amecephalus arjosensis* Biozone is followed in turn by the *Oryctocephalus indicus* and *Ptychagnostus praecurrens* biozones, the latter being essentially equivalent to the *Glossopleura* Biozone.

In La Laja Formation the traditional *Albertella* Biozone is recorded by *M. mexicana* at the top of the lower Soldano Member. However, the Nevada biostratigraphy below this is not reproduced because *Amecephalus arjosensis* and *Eokochaspis nodosa* occur in reversed order, separated stratigraphically by 19 m. This suggests that the ranges of these two species overlap rather than being mutually exclusive as they are in Nevada (Sundberg and McCollum, 2000; 2003a, 2003b; McCollum and Sundberg, 2007). In the Pioche Shale of southeastern Nevada, *E. nodosa* occurs in a single limestone bed at the base of the Comet Shale Member. *Amecephalus arjosensis* occurs after a gap of about 30 m in several localities. In outer shelf areas represented by the lower part of the Emigrant Formation at Split Mountain, southwestern Nevada, *E. nodosa* occurs through about 5 m (or possibly 7 m) of mudstones, and the lowest *A. arjosensis* occurs after a gap of about 4 m (or possibly 2 m). However, *E. nodosa* has not been found in the Goldfield Hills along depositional strike, or in the Saline Range farther to the southwest, although both areas yield *A. arjosensis*. Because of this discrepancy we recognize a combined *Amecephalus arjosensis–Eokochaspis nodosa* Biozone. It should be noted that the content of *Eokochaspis* has not been stable since it was first erected (see Systematic Paleontology below), and our identification of *E. nodosa*, like many early ptychoparioids, could be disputed.

In eastern Laurentia and around Iapetus and elsewhere there is a hiatus of variable duration in the late early Cambrian–early middle Cambrian (series 2, stage 3–series 3, stage 4). This is referred to as the Hawke Bay Event (Palmer and James, 1980; Nielsen and Schovsbo, 2011). It had been postulated to separate El Estero and Soldano members (Bordonaro, 2003) but our

biostratigraphic data and the lack of sedimentological evidence for an unconformity now suggest that it is not present.

Foglia and Vaccari (2010) reported the presence of *Glossopleura walcottii* Poulsen, 1927 at Cerro El Molle. This species



FIGURE 4—1, outcrop of 2 m thick glauconitic bioclastic grainstone at base of Soldano Member. Olenelloids and ‘simple’ ptychoparioids belonging to “*Antagmus*” occur in a 0.2 m thick interval to the left of the hammer; *Amecephalus arjosensis* occurs at the top of the unit to the right, by the spiny *chaguar* plant on the rock surface; 2, outcrop of thin-bedded lime mudstone and rubbly weathering argillaceous lime mudstone of the Soldano Member at top of Cerro El Molle section, below the deformed limestones; the recessive ~2 m thick interval yields *Mexicella mexicana*.

appears to have been recovered from deformed limestones above the argillaceous lime mudstones yielding *M. mexicana*, which accords approximately with the occurrence of a species of *Glossopleura* in undeformed limestones in the middle Soldano Member at Cerro Tres Marias (Bordonaro and Pratt, personal observ.). They also recovered a pygidium from the interval between the highest olenelloids and *G. walcotti*, which they assigned to *Fieldaspis* sp. This could be from strata above the horizon that yielded *Kochiella maxeyi* and below the interval bearing *M. mexicana*, and may be indicative of the *Poliella denticulata* Biozone. *Kochiella maxeyi* occurs in this biozone in the Pioche Shale in Pioche Hills, Nevada (Sundberg and McCollum, 2003a). However, in the Soldano Member *K. maxeyi* occurs below cranidia identified as *Eokochaspis nodosa*, the reverse of the order in the Pioche Shale.

PALEOBIOGEOGRAPHY

Globally, Cambrian polymeroid trilobites at both the generic and specific level were mostly endemic to the various cratons following the break-up of Rodinia and accompanying sea-level rise and transgression over continental margins and flooding of continental interiors. There was some interchange in outer shelf and slope settings of species capable of dispersal over long distances and adapted to deeper water environments, such as certain agnostoids, eodiscoids, oryctocephalids, olenids and others (e.g., Pratt, 1992; Babcock, 1994; Rushton and Hughes, 1995; Alvaro et al., 2003; Sundberg and McCollum, 2003b).

All five of the taxa identified to the specific level from the lower Soldano Member have been described previously from Laurentian deposits, mostly from the Great Basin but also from western Canada and one from the southern Appalachians. The Laurentian affinity of the Precordillera persisted through the Cambrian (Benedetto et al. 1999; Bordonaro et al., 2008, 2013) into the Middle Ordovician when Gondwanan taxa began to make their presence felt (Benedetto et al., 1999).

These shared occurrences do not constrain the origin of the Precordilleran terrane as a tectonic entity because of the bias in the record of early middle Cambrian successions: they are exposed intermittently along present-day western North America and in northern Greenland whereas the northeastern side of the continent preserves none (Palmer, 1971). On the other hand, the absence of the Hawke Bay Event argues against a close affinity with the Iapetus margin, or that its relative sea-level history was independent. Thus, derivation from somewhere along southern Laurentia (e.g., Thomas and Astini, 2003; Dickerson, 2012) or from a nearby part of Gondwana (Finney, 2007) are both plausible based on faunal evidence.

SYSTEMATIC PALEONTOLOGY

Specimens are housed in the paleontological collection of the Instituto Argentino de Nivología, Glaciología y Ciencias Ambientales, Mendoza (IANIGLA-PI prefix). Other prefixes: USNM, National Museum of Natural History, Smithsonian Institution, Washington, D.C.

By convention, size in the sagittal direction is long/short, whereas in the transverse direction it is broad or wide/narrow. Preoccipital glabellar length is measured anterior of the occipital furrow. Width of the glabella is width at occipital furrow.

- Class TRILOBITA Walch, 1771
- Order PTYCHOPARIIDA Swinnerton, 1915
- Suborder PTYCHOPARIINA Richter, 1932
- Superfamily PTYCHOPARIOIDEA Matthew, 1887
- Family PTYCHOPARIIDAE Matthew, 1887

Remarks.—Owing to the uncertainty of classification and phylogeny of the ptychopariids and the many species for which critical sclerites are unknown (Fortey in Whittington et al., 1997), an inclusive diagnosis and discussion are not attempted.

Subfamily uncertain

Remarks.—Palmer (in Palmer and Halley, 1979, p. 99) suggested that a case can be made for a higher level taxon that incorporates the early middle Cambrian ptychoparioids *Kochaspis* Resser, 1935 (type species *Crepicephalus liliana* Walcott, 1886), *Caborcella* Lochman, 1948 (type species *C. arrosensis* Lochman, 1948), *Kochiellina* Palmer in Palmer and Halley, 1979 (type species *K. groomensis* Palmer in Palmer and Halley, 1979), *Nyella* Palmer in Palmer and Halley, 1979 (type species *Poulsenia granosa* Resser, 1939b), *Schistometopus* Resser, 1938a (type species *S. typicalis* Resser, 1938), and possibly *Kochina* Resser, 1935 (type species *Olenopsis americanus* Walcott, 1912) and *Kochiella*. He referred to them informally as ‘kochaspids.’ To this group Sundberg and McCollum (2000, 2002) added *Amecephalus* Walcott, 1924 (type species *Ptychoparia piochensis* Walcott, 1886), *Eokochaspis* Sundberg and McCollum, 2000 (type species *E. nodosa* Sundberg and McCollum, 2000) and *Hadrocephalites* Sundberg and McCollum, 2002 (type species *H. lyndonensis* Sundberg and McCollum, 2002). *Tonopahella* Sundberg and McCollum, 2003b (type species *T. goldfieldensis* Sundberg and McCollum, 2003b) and *Amecephalites* Eddy and McCollum, 1998 (type species *A. sundbergi* Eddy and McCollum, 1998) are probably also ‘kochaspids.’ Some species assigned to *Onchocephalus* Resser, 1937 (type species *Ptychoparia thia* Walcott, 1917b) might also be too, but the validity and content of this genus are unclear (Sundberg and McCollum, 2000, p. 611; 2003b, p. 974). *Provedoria* Lochman, 1948 (type species *P. starquistae* Lochman, 1948) was based on cranidia and free cheeks (see also Lochman in Cooper et al., 1952, p. 156). The cranidium is similar to those of other ‘kochaspids’ and this species may prove to be a junior synonym of one.

A fundamental problem with many of these genera is that they were based on insufficient material (Sundberg, 2004, p. 928). Sundberg (2004) also noted that many of the features used to define taxa are continuous characters, and both cladistical analysis and traditional taxonomic criteria do not separate genera into clear-cut groups. Some taxa lack sufficiently derived characters. Nevertheless, four comparatively well-defined ‘kochaspid’ subclades are revealed, named after the genera *Amecephalus*, *Kochiella*, *Hadrocephalites*, *Kochaspis* and *Mexicella*, plus a miscellaneous one. Members of these groups are recognized in La Laja Formation. However, because these groups, with the exception of *Mexicella*, contain species assigned to other genera, most genera as presently constituted are clearly polyphyletic and in need of major revision (Sundberg, 2004).

AMECEPHALUS Walcott, 1924

Type species.—*Ptychoparia piochensis* Walcott, 1886 from the Pioche Shale, southeastern Nevada, by original designation.

Remarks.—This genus has been discussed at length by Sundberg and McCollum (2000; Sundberg, 1999). *Alokistocare* Lorenz, 1906 (type species *Conocephalites subcoronata* Hall and Whitfield, 1877) is distinguished from it mainly by the presence of a median swelling of the preglabellar field and anterior border. In addition, cranidia have deeper dorsal furrows, the rostral plate is narrower, and the pygidium is subquadrate in outline rather than elliptical and the axis is less inflated. According to Sundberg’s (1999) concept, *Amecephalus* is a sister group to *Alokistocare* and ehmaniellids, and contains species that occur in the *Plagiura* through *Glossopleura* biozones, whereas those

belonging to *Alokistocare* occur in the *Ehmaniella* and *Bolaspiddella* biozones.

Sundberg and McCollum (2000) considered *Amecephalus* to contain eight species: *A. piochensis*, *A. agnesensis* (Walcott, 1912), *A. althea* (Walcott, 1916a), *A. cleora* (Walcott, 1917b), *A. gordonensis* (Resser, 1935), *A. laticaudum* (Resser, 1939a), *A. idahoense* (Resser, 1939a) and *A. arrojensis* Lochman in Cooper et al., 1952. To this has been added *A. jamisoni* Robison and Babcock, 2011. *Amecephalus laticaudum* has been considered a synonym of *A. althea*, as is *Alokistocare septum* Resser, 1939a (Foster, 2011, p. 110).

In *A. cleora* the anterior border is twice as long as the preglabellar field (Rasetti, 1951, pl. 15, figs. 12–20), whereas the opposite holds true in *A. piochensis* (Walcott, 1925, pl. 15, figs. 8–10), *A. gordonensis* (Walcott, 1917b, pl. 6, fig. 4c) and *A. idahoense* (Resser, 1939a, pl. 4, fig. 9), and they are similar in length in *A. agnesensis* (Rasetti, 1951, pl. 10, figs. 11–14), *A. althea* (and *A. laticaudum*; Resser, 1939a, pl. 4, figs. 15–19; Fritz, 1968, pl. 40, fig. 17; Sundberg, 2005, fig. 6.6; Foster, 2011, fig. 7.4–7.7) and *A. arrojensis* (Sundberg and McCollum, 2000, fig. 1.1, 1.2, 1.4–1.7). With respect to the last three, the frontal area is shortest in *A. arrojensis*. In addition, the thoracic pleural spines in *A. cleora* (Rasetti, 1951, pl. 15, fig. 12) are much longer than those of *A. agnesensis* (Rasetti, 1951, pl. 10, figs. 11–13) and *A. piochensis* (Walcott, 1925, pl. 15, fig. 9).

Cranidia of *A. althea* from the *Glossopleura* Biozone in the Bright Angel Shale of northern Arizona show a median swelling in the preglabellar field and anterior border (Foster, 2011, fig. 4.4–4.7). The holotypes of *A. idahoense* and *A. laticaudum* from the *Glossopleura* Biozone in the Spence Shale of northern Utah are crushed but also show a weak swelling (Resser, 1939a, pl. 4, figs. 9, 17, 18). Numerous specimens in private collections also show this although it is variably expressed (e.g., Gunther and Gunther, 1981, pl. 3, figs. B, C, pl. 4, figs. B, C). In both, the pygidium is subquadrate in outline. Probably these species should be returned to *Alokistocare* to which they were originally assigned.

Amecephalus jamisoni also from the Spence Shale is characterized by spines on the occipital ring and on the axial lobe of the thoracic segments (Robison and Babcock, 2011, fig. 15.1–15.4). The fixed cheek is somewhat narrower than in older species of *Amecephalus*. The posterior border of the pygidium possesses a median indentation. It is not clear if this species belongs to genus.

Occurring with a species of *Albertella* stratigraphically above *A. arrojensis* in the Arroj Formation northwestern Sonora is *Provedoria starquistae* Lochman, 1948, the type and only species of *Provedoria* Lochman, 1948 (Lochman in Cooper et al., 1952). This species is based on cranidia and free cheeks that closely resemble those upon which *Strotocephalus arrojensis* Lochman in Cooper et al., 1952 was based. In *P. starquistae* the lateral glabellar furrows are deeper and the fixed cheek is narrower, about half the width of the glabella. However, the width of the free cheek in the original cranidia of *S. arrojensis* is about equal to it, whereas in cranidia assigned to *A. arrojensis* by Sundberg and McCollum (2000, 2003b) it is about two-thirds its width. It is possible these differences may be encompassed by the range of intraspecific variation observed in larger collections (Figs. 5.1–5.13, 6.1–6.5). Should *P. starquistae* and *A. arrojensis* prove synonymous, the former would have priority.

AMECEPHALUS ARROJENSIS (LOCHMAN in Cooper et al., 1952)
Figures 5.1–5.13, 6.1–6.20

1952 *Strotocephalus arrojensis* LOCHMAN in Cooper et al.,
p. 157, pl. 21, figs. 29–34.

2000 *Amecephalus arrojensis*; SUNDBERG AND MCCOLLUM,
p. 607, fig. 5.1–5.13.

2003b *Amecephalus arrojensis*; SUNDBERG AND MCCOLLUM,
p. 966, pl. 3, fig. 12.

Holotype.—A cranidium (USNM 115805a) from the Arroj Formation, northwestern Sonora (Lochman in Cooper et al., 1952, pl. 21, figs. 31–33).

Material.—Twenty-six (26) holaspid cranidia (IANIGLA-PI 1111, 1112a, b, 1113–1115, 1116a–c, 1117, 1119, 1134, 1340, 1341, 1342a, 1343, 1344, 1345a, b, 1346a, b, 1347, 1348, 1352, 1356, 1363b), three meraspid cranidia (IANIGLA-PI 1124b, 1125, 1362a), one hypostome (IANIGLA-PI 1124a), one rostral plate (IANIGLA-PI 1120), nine free cheeks (IANIGLA-PI 1121–1123, 1150, 1351, 1153–1355, 1362b), two thoracic segments (IANIGLA-PI 1116d, 1118), four pygidia (IANIGLA-PI 1349, 1358–1360), and one protaspide (IANIGLA-PI 1363a), plus some unnumbered sclerite fragments.

Occurrence.—In thin-bedded glauconitic grainstone 1 m above base of Soldano Member, La Laja Formation, Cerro El Molle, San Juan (*Amecephalus arrojensis*–*Eokochaspis nodosa* Biozone); base of Arroj Formation, Caborca, Sonora; upper Comet Shale Member, Pioche Shale, and Susan Duster Limestone, southeastern Nevada (*Amecephalus arrojensis* Biozone); Emigrant Formation, southwestern Nevada (*Amecephalus arrojensis* Biozone).

Remarks.—*Amecephalus arrojensis* in the Soldano Member conforms with this species in the Pioche Shale as characterized by Sundberg and McCollum (2000). Prosopon of cranidia and free cheeks is finely pitted and caeca are visible on the preglabellar field of some specimens. The cranidium is similar to that of *Kochiella maxeyi* except that the glabella is somewhat more elongate with a slight constriction between S2 and S3. The palpebral lobe varies slightly with respect to the preoccipital length of the glabella, but is shorter than that of *K. maxeyi*. Meraspid stages have hitherto not been illustrated, and these show a typical rectangular glabella that becomes more anteriorly tapered in holaspides. The protaspide is typical for generalized ptychoparioids and resembles those attributed previously to *Amecephalus* sp. (Hu, 1985, pl. 3, figs. 12–14).

Genus KOCHIELLA Poulsen, 1927

Type species.—*Kochiella tuberculata* Poulsen, 1927 from the Cape Kent Formation, northwestern Greenland, by original designation.

Diagnosis.—Genus of Ptychopariidae with cranidium having frontal area in length half to nearly equal to that of preoccipital glabella; anterior border flat, in length about equal to that of preglabellar field. Anterior course of facial suture divergent. Fixed cheek wide, gently upsloping. Pygidium bearing posteriorly directed pleural furrows; posterior border lobate to bluntly pointed on either side of median indentation. (Modified from Sundberg and McCollum, 2002, p. 79)

Remarks.—*Kochiella* has been reviewed at length by Sundberg and McCollum (2002) who noted that *Eiffelaspis* Chang, 1963 is a junior synonym of *Kochiella* because its type species, *K. maxeyi* Rasetti, 1951, is retained in *Kochiella*. A difficulty in evaluating this genus is the fact that Poulsen (1927) erected it for four species, all based only on cranidia with some free cheeks, from the Cape Kent Formation. Thus it is uncertain whether or not all of Poulsen's (1927) species can be sustained in the absence of more complete material. Sundberg and McCollum (2002) considered *K. propinqua* and *K. arcana* to be junior synonyms of *K. tuberculata*, and *K. gracilis* to be distinct mainly because of the absence of tubercles. It is not clear, however, if the presence or absence of tuberculate or granulate prosopon is diagnostic at the specific level in 'kochaspids' because, for example, some specimens of the related *Eokochaspis nodosa* have fine tubercles

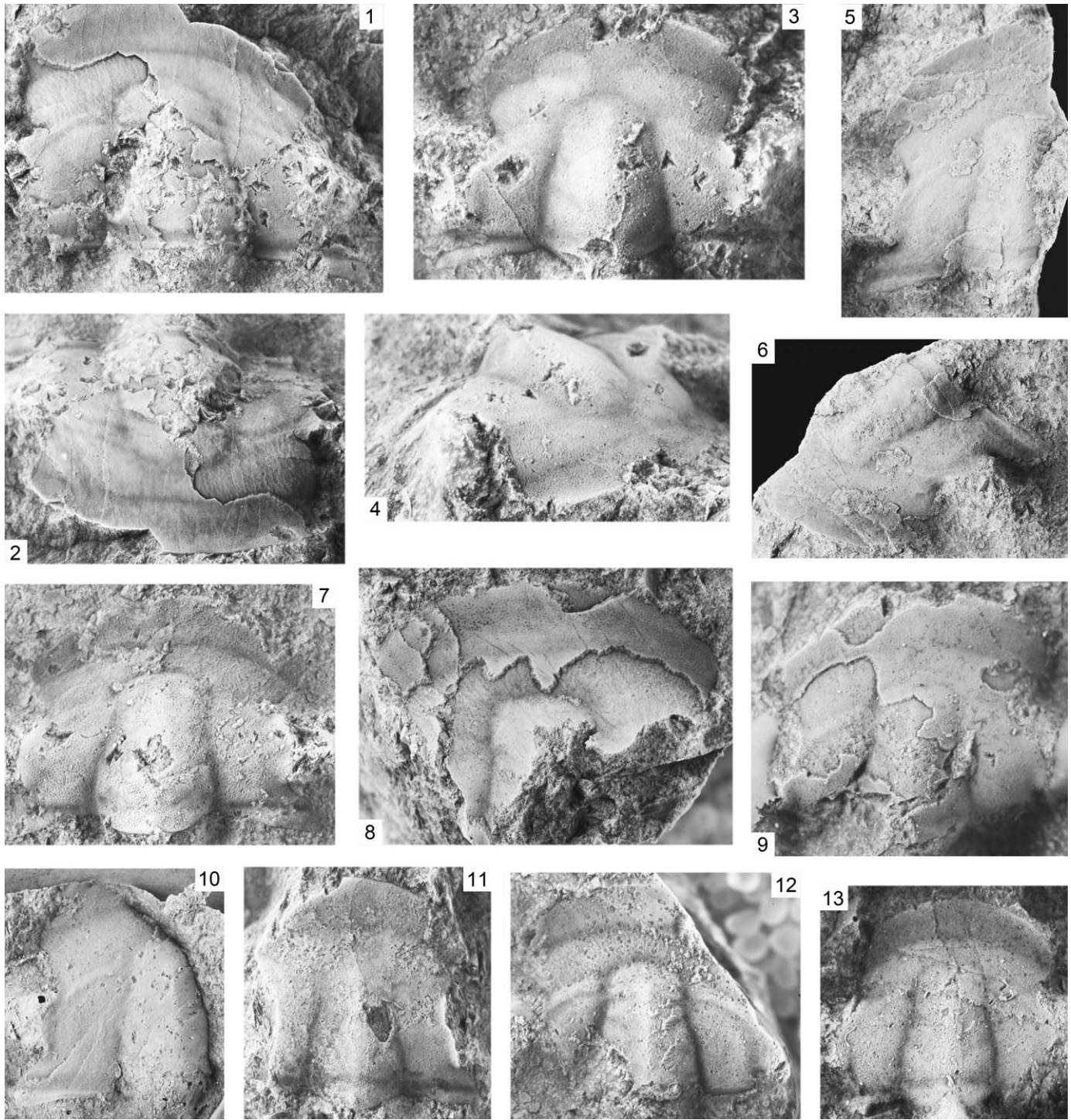


FIGURE 5—*Amecephalus arrososensis* (Lochman in Cooper et al., 1952) from the middle Cambrian Soldano Member, La Laja Formation, at Cerro El Molle, San Juan, Argentina (collection +1 m): 1, 2, cranidium (dorsal, anterior), IANIGLA-PI 1342a, $\times 4$; 3, 4 cranidium (dorsal, anterior-oblique), IANIGLA-PI 1352, $\times 8.5$; 5, 6, cranidium (dorsal, anterior-oblique), IANIGLA-PI 1111, $\times 3$; 7, cranidium (dorsal), IANIGLA-PI 1346a, $\times 6.5$; 8, cranidium (dorsal), IANIGLA-PI 1345a, $\times 6$; 9, cranidium (dorsal), IANIGLA-PI 1117, $\times 5$; 10, cranidium (dorsal, fragment; latex cast), IANIGLA-PI 1112a, $\times 3.5$; 11, cranidium (dorsal), IANIGLA-PI 1344, $\times 6.5$; 12, cranidium (dorsal), IANIGLA-PI 1343, $\times 4$; 13, cranidium (dorsal; latex cast), IANIGLA-PI 1345b, $\times 7.5$.

while some do not (Sundberg and McCollum, 2000, fig. 7.1–7.4, 7.6, 7.7, 7.11; 2003b, pl. 2, fig. 1). In a single pygidium associated with the various cranidia in the Cape Kent Formation, assigned originally to *Crepicephalus* cf. *cecinna* Walcott, 1917b, the pleural field merges into a posteriorly directed stout spine. It was re-assigned first to *K. tuberculata* by Resser (1935; Poulsen, 1964), thence to *Hadrocephalites* by Sundberg and McCollum

(2002) even though no cranidia representing that genus were illustrated by Poulsen (1927). Similarly, *Inglefieldia* Poulsen, 1927 (type species *I. porosa* Poulsen, 1927) was erected for six species in the Cape Kent Formation plus *Ptychoparia thia* Walcott, 1917b from the Mount Whyte Formation of the southern Rocky Mountains, Canada. These species were based on cranidia only and it is likewise uncertain if they are all valid.

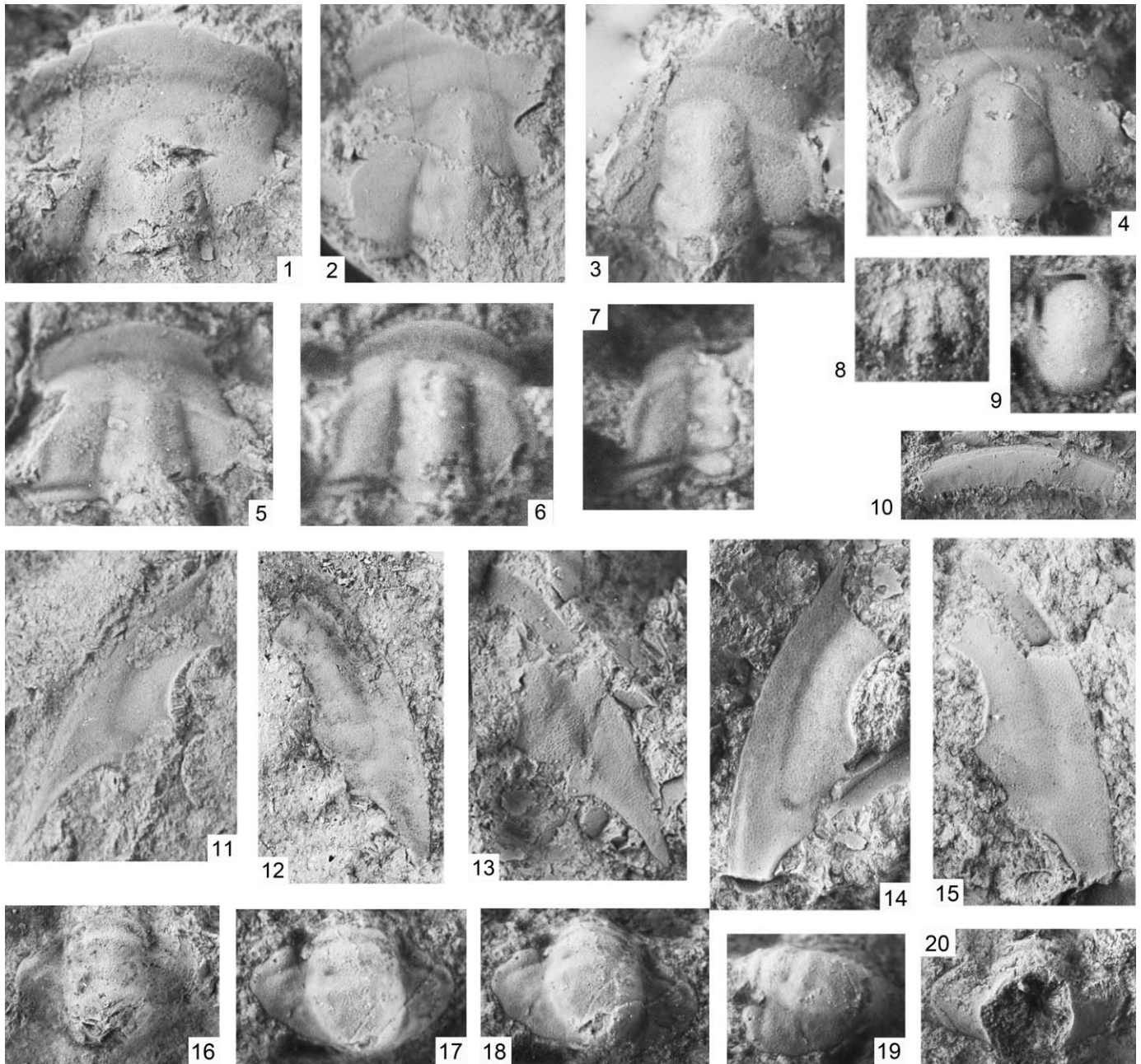


FIGURE 6—*Amecephalus arjosensis* (Lochman in Cooper et al., 1952) from the middle Cambrian Soldano Member, La Laja Formation, at Cerro El Molle, San Juan, Argentina (collection +1 m): 1, cranidium (dorsal), IANIGLA-PI 1113, $\times 5.5$; 2, cranidium (dorsal), IANIGLA-PI 1114, $\times 8$; 3, cranidium (dorsal), IANIGLA-PI 1116c, $\times 10$; 4, cranidium (dorsal), IANIGLA-PI 1112b, $\times 9$; 5, cranidium (dorsal), IANIGLA-PI 1119, $\times 12$; 6, meraspid cranidium (dorsal), IANIGLA-PI 1124b, $\times 24$; 7, meraspid cranidium (dorsal), IANIGLA-PI 1125, $\times 18$; 8, protaspide (dorsal), IANIGLA-PI 1363a, $\times 18$; 9, hypostome (ventral), IANIGLA-PI 1124a, $\times 20$; 10, rostral plate (ventral), IANIGLA-PI 1120, $\times 4.5$; 11, free cheek (dorsal), IANIGLA-PI 1121, $\times 10$; 12, free cheek (dorsal; latex cast), IANIGLA-PI 1353, $\times 6$; 13, free cheek (dorsal; partly latex cast), IANIGLA-PI 1122, $\times 9$; 14, free cheek (dorsal), IANIGLA-PI 1350, $\times 9$; 15, free cheek (dorsal), IANIGLA-PI 1354, $\times 8$; 16, pygidium (dorsal), IANIGLA-PI 1358, $\times 6$; 17–19, pygidium (dorsal, posterior, lateral), IANIGLA-PI 1359, $\times 12$; 20, pygidium (dorsal; missing axis), IANIGLA-PI 1349, $\times 7$.

Only a few rostral plates and free cheeks with their anterior portions intact have been illustrated for these taxa. The rostral plates of *Amecephalus arjosensis* (Lochman in Cooper et al., 1952), *E. nodosa* Sundberg and McCollum, 2000 and *E. delamarensis* Sundberg and McCollum, 2000, figs. 5.8, 7.5, 7.8–7.10; Webster, 2011, fig. 28.1, 28.2). They are wider than that of *Crassifimbria walcotti* (Resser, 1937) (Webster, 2011, fig. 22.1, 22.2).

Poulsen (1964, p. 20) regarded the median flexure of the anterior border furrow to be distinctive of *K. tuberculata*. By contrast, Sundberg and McCollum (2002) noted that the anterior border furrow can be effaced medially (*K. mackenziensis* Norford, 1968) or evenly curved (*K. maxeyi*). They considered the nature of this furrow to be insufficient to warrant generic distinction. The glabella of the various species they assigned to *Kochiella* is either straight-sided or slightly constricted at S3. The pygidial pleural field ranges in posterior outline from triangular and

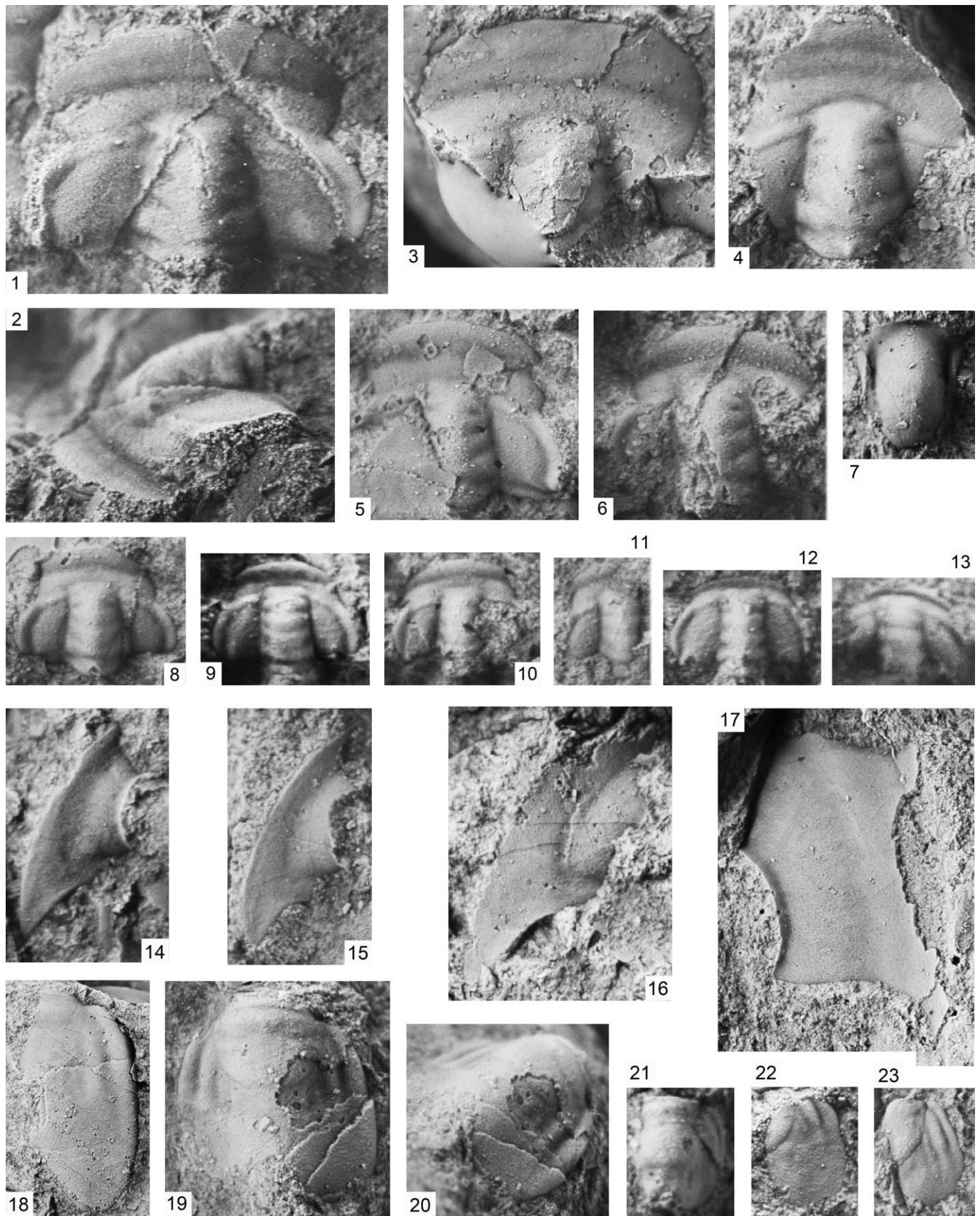


FIGURE 7—*Kochiella maxeyi* Rasetti, 1951 from the middle Cambrian Soldano Member, La Laja Formation, at Cerro El Molle, San Juan, Argentina (collection +14 m): 1, 2, cranium (dorsal, anterior-oblique), IANIGLA-PI 1126a, $\times 15$; 3, cranium (dorsal), IANIGLA-PI 1127, $\times 9$; 4, cranium (dorsal), IANIGLA-PI 1134a, $\times 12$; 5, cranium (dorsal; latex cast), IANIGLA-PI 1128, $\times 17.5$; 6, cranium (dorsal), IANIGLA-PI 1130, $\times 17$; 7, hypostome (ventral), IANIGLA-PI

pointed as in *K. mansfieldi* Resser, 1939b, *K. chares* (Walcott, 1917a), *K. augusta* (Walcott, 1886), and *K. rasettii* Sundberg and McCollum, 2002), to lobate as in *K. arenosa* Resser, 1939b and *K. maxeyi*. Sundberg (2004) noted that species of *Kochiella* fall into two clades.

KOCHIELLA MAXEYI Rasetti, 1951

Figure 7.1–7.23

- 1951 *Kochiella? maxeyi* RASETTI, p. 228, pl. 13, figs. 5, 8.
 ?1951 *Kochiella?* cf. *K. maxeyi*; RASETTI, p. 229, pl. 13, fig. 9.
 1957 *Kochiella? maxeyi*; RASETTI, p. 961, pl. 120, figs. 1–3.
 1963 *Eiffelaspis maxeyi*; CHANG, p. 479.
 1964 *Kochiella? maxeyi*; POULSEN, p. 20.
 2002 *Kochiella maxeyi*; SUNDBERG AND MCCOLLUM, p. 85, fig. 7.10.

Diagnosis.—A species of *Kochiella* with frontal area in length half that of preoccipital glabella. Glabella in outline subquadrate to triangular, straight-sided. Palpebral lobe in length three-quarters that of preoccipital glabella. Genal spine short. Pygidium narrow, elongate; pleural field flat to downsloping; posterior border bilobate in outline with median notch.

Holotype.—Cranidium (USNM 116114) from the Mount Whyte Formation, southern Rocky Mountains, Canada (Rasetti 1951, pl. 13, figs. 5–7).

Material.—Six holaspid cranidia (IANIGLA-PI 1126a, 1127, 1128, 1129, 1130, 1131, 1134a), five meraspid cranidia (IANIGLA-PI 1126b, 1132, 1134b, 1137), one hypostome (IANIGLA-PI 1142), six free cheeks (IANIGLA-PI 1133a, 1138, 1140, 1144), and six pygidia (IANIGLA-PI 1133b, c, 1136, 1139, 1143a, 1143b).

Occurrence.—Thin-bedded grainstone 14 m above base of Soldano Member, La Laja Formation, Cerro El Molle, San Juan (*Amecephalus arjosensis*–*Eokochaspis nodosa* Biozone); Mount Whyte Formation, southern Rocky Mountains, Canada (*Plagiura*–*Kochaspis* Biozone); Log Cabin Member, Pioche Shale, southeastern Nevada (*Poliella denticulata* Biozone).

Remarks.—The single known pygidium of *Kochiella arenosa* Resser, 1939b is a sandstone mold (Resser, 1939b, pl. 11, fig. 9; Sundberg and McCollum, 2002, fig. 5.7) and too poorly preserved to assess. It also possesses a bilobate posterior outline, but the pleural field appears to be concave, while that of *K. maxeyi* is by and large flat and variably downsloping. It is possible that larger collections of the former might show it to be a senior synonym.

In other species of *Kochiella* where pygidia are known, the posterior pygidial margin is bluntly pointed on either side of the median notch (Sundberg and McCollum, 2002). Pygidia from the Soldano Member vary in length, and some (Fig. 7.19, 7.21) are slightly shorter than others in the same collection (Fig. 7.18) and those described from the Mount Whyte Formation (Rasetti, 1957, pl. 120, figs. 1–3) and Pioche Shale (Sundberg and McCollum, 2002, fig. 7.10). The hypostome is newly described herein. It is of natant type and similar to those of species in related genera (Sundberg and McCollum, 2000, figs. 5.13, 7.9, 7.10, 8.4, 8.5).

Meraspid cranidia for a *Kochiella* species are illustrated for the first time. They exhibit long palpebral lobes and a glabella that is subrectangular in outline. The glabella becomes more tapered in holaspides. The largest specimen in the collection is half the size of the type cranidia. Based on their longer palpebral lobes, cranidia from the Soldano Member may be early holaspides.

Cranidia belonging to *K. crito* (Walcott, 1917b) from the Mount Whyte Formation lack a granulate or tuberculate prosopon (Sundberg and McCollum, 2002, fig. 5.8, 5.9). By contrast, cranidia belonging to other species are variably tuberculate (Sundberg and McCollum, 2002, figs. 5.1, 6.1, 6.2, 7.1, 7.4, 8.1, 8.4–8.6, 8.9, 9.1, 9.4, 9.5), and cranidia of *K.? maxeyi* and *K.? cf. K. maxeyi* are similar in this regard (Rasetti, 1951, pl. 9, figs. 5–9). Three pygidia assigned to *K.? maxeyi* possess sparse tubercles (Rasetti, 1957, pl. 120, figs. 1–3), whereas the pygidium assigned to *K. maxeyi* by Sundberg and McCollum (2002, fig. 7.10) is smooth. Pygidia in the Soldano Member also lack tubercles, and cranidia have a prosopon of small pits along with coarse granules or small tubercles on the posterior part of the glabella. Given these observations, differences in the nature of the prosopon in *K. maxeyi* are taken here as diagnostically unimportant and considered due to intraspecific variation.

KOCHIELLA species indeterminate

Figure 12.4, 12.5

Description.—Cranidium is characterized by a glabella that is subquadrate in outline with three pairs of lateral glabellar furrows. The anterior course of the facial suture is divergent. The moderately wide frontal area consists of a preglabellar field that is gently depressed medially, and a gently convex anterior border that is almost twice as long as the preglabellar field and divided from it by a shallow anterior border furrow. The fixed cheek is broad, being two-thirds as wide as the glabella. It bears a relatively well-defined ocular ridge; the long, posteriorly located palpebral lobe is in length two-thirds that of the preoccipital glabella. The occipital ring appears to lack a median node; the surface is either smooth or has finely granulate prosopon. The free cheek has a wide genal area, shallow border furrow and wide lateral border.

Material.—One cranidium (IANIGLA-PI 585) and one free cheek (IANIGLA-PI 588).

Occurrence.—Thin-bedded grainstone 6 m above base of Soldano Member, La Laja Formation, Cerro El Molle, San Juan (*Amecephalus arjosensis*–*Eokochaspis nodosa* Biozone).

Remarks.—With the long, posteriorly located palpebral lobe the incomplete cranidium closely resembles that of *Kochiella maxeyi* Rasetti, 1951 which occurs 8 m above. The absence of an associated pygidium, however, precludes a specific identification.

Genus EOKOCHASPIS Sundberg and McCollum, 2000

Type species.—*Eokochaspis nodosa* Sundberg and McCollum, 2000 from the Pioche Shale, southeastern Nevada, by original designation.

Diagnosis.—Genus of Ptychopariidae with cranidium having frontal area in length half that of preoccipital glabella, bearing slight median swelling. Moderately short anterior border flat to gently convex, in length equal to that of preglabellar field. Anterior course of facial suture straight forward to slightly convergent. Rostral plate in width five times its length. Glabella subquadrate in outline. Fixed cheek gently convex, horizontal to slightly downsloping; palpebral lobe in length two-fifths that of the preoccipital glabella. Pygidium elliptical in outline with broad, shallow median indentation of posterior border. (Modified from Sundberg and McCollum, 2000, p. 610.)

Remarks.—As noted by Sundberg and McCollum (2000;

1142, ×11; 8, cranidium (dorsal; latex cast), IANIGLA-PI 1131, ×16; 9, meraspid cranidium (dorsal; partly latex cast), IANIGLA-PI 1137, ×16; 10, meraspid cranidium (dorsal), IANIGLA-PI 1126b, ×21; 11, meraspid cranidium (dorsal), IANIGLA-PI 1129, ×17.5; 12, meraspid cranidium (dorsal), IANIGLA-PI 1134b, ×21; 13, meraspid cranidium (dorsal), IANIGLA-PI 1132, ×24; 14, free cheek (dorsal; latex cast), IANIGLA-PI 1140, ×19.5; 15, free cheek (dorsal), IANIGLA-PI 1133a, ×12.5; 16, free cheek (dorsal), IANIGLA-PI 1138, ×12; 17, free cheek (dorsal; latex cast), IANIGLA-PI 1144, ×11; 18, pygidium (dorsal; right side), IANIGLA-PI 1143a, ×5.5; 19, 20, pygidium (dorsal, posterior-oblique), IANIGLA-PI 1143b, ×12.5; 21, pygidium (dorsal; right side), IANIGLA-PI 1136, ×20; 22, pygidium (dorsal; right side), IANIGLA-PI 1139, ×10; 23, pygidium (dorsal; right side), IANIGLA-PI 1133b, ×10.

Sundberg, 2004), *Eokochaspis* is part of a group of inadequately understood genera with similar cranidia for which other sclerites are largely unknown and whose familial affinity or affinities is unclear. This includes *Antagmus* Resser, 1936 (type species *Ptychoparia teucer* Walcott, 1886), *Crassifimbra* Lochman, 1947 (type species *Onchocephalus walcotti* Resser, 1937), *Elrathina* Resser, 1937 (type species *Conocephalites cordillerae* Rominger, 1887), *Eoptychoparia* Rasetti, 1955 (type species *E. normalis* Rasetti, 1955), *Onchocephalites* Rasetti, 1957 (type species *O. levis* Rasetti, 1957), *Ptychoparella* Poulsen, 1927 (type species *P. brevicauda* Poulsen, 1927), *Syspacephalus* Resser, 1936 (type species *Agraulos charops* Walcott, 1917b), and possibly *Illtydaspis* Fritz, 1991 (type species *I. quartetensis* Fritz, 1991) and *Paraantagmus latus* Yuan and Li, 1999, among others. They are variably convex. A median swelling of the preglabellar field and a backward inflection of the anterior border furrow are variably expressed. The anterior course of the facial suture ranges from straight forward to gently convergent. The glabella is typically straight-sided or slightly curved inward, and its anterior lobe transverse to gently rounded. The palpebral lobes are located opposite the preoccipital glabellar mid-point or anterior to it. It is not clear whether or not they all belong to the 'kochaspid' plexus.

Sundberg and McCollum (2000) placed five species in *Eokochaspis*: *E. nodosa*, *E. delamarensis* Sundberg and McCollum, 2000, *E. longispina* Sundberg and McCollum, 2000, *E. metalaspis* Sundberg and McCollum, 2000, and *E. piochensis* Palmer in Palmer and Halley, 1979, with *E.?* *cabinensis* Sundberg and McCollum, 2003a being a possible a sixth. With further analysis Sundberg (2004; Webster, 2011) noted that *Eokochaspis* is likely polyphyletic. The holotype of *E. delamarensis* has shallower dorsal furrows, a less convex and anteriorly more tapered glabella, and a shorter palpebral lobe than in *E. nodosa* (Sundberg and McCollum, 2000, fig. 8.1–8.3). The holotype of *E. longispina* has a more tapered glabella, a divergent anterior suture, and a shorter palpebral lobe (Sundberg and McCollum, 2000, fig. 10.1–10.3). The holotype of *E. piochensis* also has a more tapered glabella and shorter palpebral lobe (Palmer in Palmer and Halley, 1979, pl. 7, fig. 4). Whether or not it belongs to *Eoptychoparia* Rasetti, 1955 to which it was originally assigned, is uncertain (see Geyer and Peel, 2011, p. 520). In addition to the same differences, the anterior border of *E.?* *cabinensis* is relatively long. Webster (2011) reassigned *E. metalaspis* to *Crassifimbra*?. We sustain *Eokochaspis* based only on the type species and modify the diagnosis accordingly.

Intraspecific and ontogenetic variation in *C. walcotti*, *C.?* *metalaspis* and *E. nodosa* studied by Webster (2011) showed that with holaspid growth the frontal area lengthens with respect to the length of the glabella, and there is an increased tapering of the glabella.

EOKOCHASPIS NODOSA Sundberg and McCollum, 2000

Figure 8.1–8.10

- 2000 *Eokochaspis nodosa* SUNDBERG AND MCCOLLUM, p. 611, fig. 7.1–7.20.
 2003b *Eokochaspis nodosa*; SUNDBERG AND MCCOLLUM, p. 967, pl. 2, figs. 1, 2, 4.
 2011 *Eokochaspis nodosa*; WEBSTER, p. 218, figs. 7.1–7.20, 28.1–28.29, 29.1–29.31.
 2011 *Eokochaspis nodosa*; WEBSTER AND ZELDITCH, fig. 1C, 1D.

Holotype.—Cranidium (USNM 497818) from the Comet Shale Member of the Pioche Shale, southeastern Nevada (Sundberg and McCollum 2000, fig. 7.1–7.3).

Material.—Nine cranidia (IANIGLA-PI 571a, 572, 573, 574a, b, 575, 576, 578, 579) and one free cheek (IANIGLA-PI 577).

Occurrence.—Thin-bedded grainstones 20, 21 and 24 m above base of Soldano Member, La Laja Formation, Cerro Molle, San Juan (*Amecephalus arrojosensis*–*Eokochaspis nodosa* Biozone); Comet Shale Member, Pioche Shale, southeastern Nevada (*Eokochaspis nodosa* Biozone); Emigrant Formation, southwestern Nevada (*Eokochaspis nodosa* Biozone).

Remarks.—Although pygidia are lacking, cranidia concur fairly well with this species as amplified by Webster (2011) based on silicified material. However, the anterior border is slightly more curved and slightly less arched than in most holaspid cranidia from Nevada. A faint median swelling in the anterior border and depression in the preglabellar field are variably expressed in cranidia from both areas. Glabellar outline ranges from straight-sided to slightly outward-curving, with one specimen showing a gentle constriction opposite S2 (Fig. 8.7), whereas those from Nevada are more commonly straight-sided, although the degree of tapering varies somewhat. However, larger cranidia, similar in size to those in the Soldano Member, show a comparable range in glabellar outline (Webster, 2011, fig. 7.1–7.4, 7.9–7.12, 7.17). The length of the palpebral lobe is about 0.4–0.45 times that of the preoccipital glabella, whereas in collections from Nevada it is 0.45–0.5 (Webster, 2011) and 0.35–0.45 (Sundberg and McCollum, 2000). The palpebral ridge is somewhat less distinct as well. These are small differences that are taken as due to intraspecific variation (cf. Webster, 2011).

HADROCEPHALITES Sundberg and McCollum, 2002

Type species.—*Hadrocephalites lyndonensis* Sundberg and McCollum, 2002 from the Pioche Shale, southeastern Nevada, by original designation.

Remarks.—*Schistometopus* Resser, 1938a (type species *S. typicalis* Resser, 1938a) is founded on a compacted cranidium lacking a preglabellar field but with a longer, gently tapering glabella. Because of its poor preservation, Sundberg and McCollum (2002) advocated that the genus be restricted to the type species, and erected *Hadrocephalites* to include several new species plus *Crepicephalus cecinna* Walcott, 1917b, *Ptychoparia carina* Walcott, 1917b, *S. convexus* Rasetti, 1951 (also Rasetti, 1957), and cranidia assigned to *Schistometopus* spp. by Palmer (in Palmer and Halley, 1979, pl. 8, figs. 1, 2, 6). Most of these have a short preglabellar field with the transverse to gently curved anterior border cut sharply obliquely by the suture; most possess granulate or sparsely pustulose prosopon. Pygidia attributed to most cranidia possess a pair of stout posterior border spines, and because of the pygidial similarity Sundberg and McCollum (2002) considered *Hadrocephalites* to be related to *Kochiella* Poulsen, 1927. These are all from the traditional *Plagiura–Poliella* Biozone of southern Nevada and adjacent California and the *Plagiura–Kochaspis* Biozone of the southern Rocky Mountains of western Canada. Sundberg (2004) reassigned *S. collaris* Rasetti, 1951 to *Caborcella* Lochman, 1948 (type species *C. arrojosensis* Lochman, 1948). *Schistometopus?* *minor* Rasetti, 1957 cannot be matched to a pygidium so its generic placement is uncertain (Sundberg, 2004).

HADROCEPHALITES species indeterminate

Figure 12.3

Material.—One cranidium (IANIGLA-PI 1376b).

Occurrence.—Rubbly weathering, thin-bedded argillaceous lime mudstones 48–50 m above base of Soldano Member, La Laja Formation, Cerro El Molle, San Juan (*Mexicella mexicana* Biozone).

Remarks.—The incomplete cranidium is assigned to *Hadrocephalites* on the basis of the absence of the preglabellar field and the sharply oblique trace of the suture across the transverse anterior border. However, the glabella lacks well-incised lateral glabellar furrows, the ocular ridge is absent, and the surface is

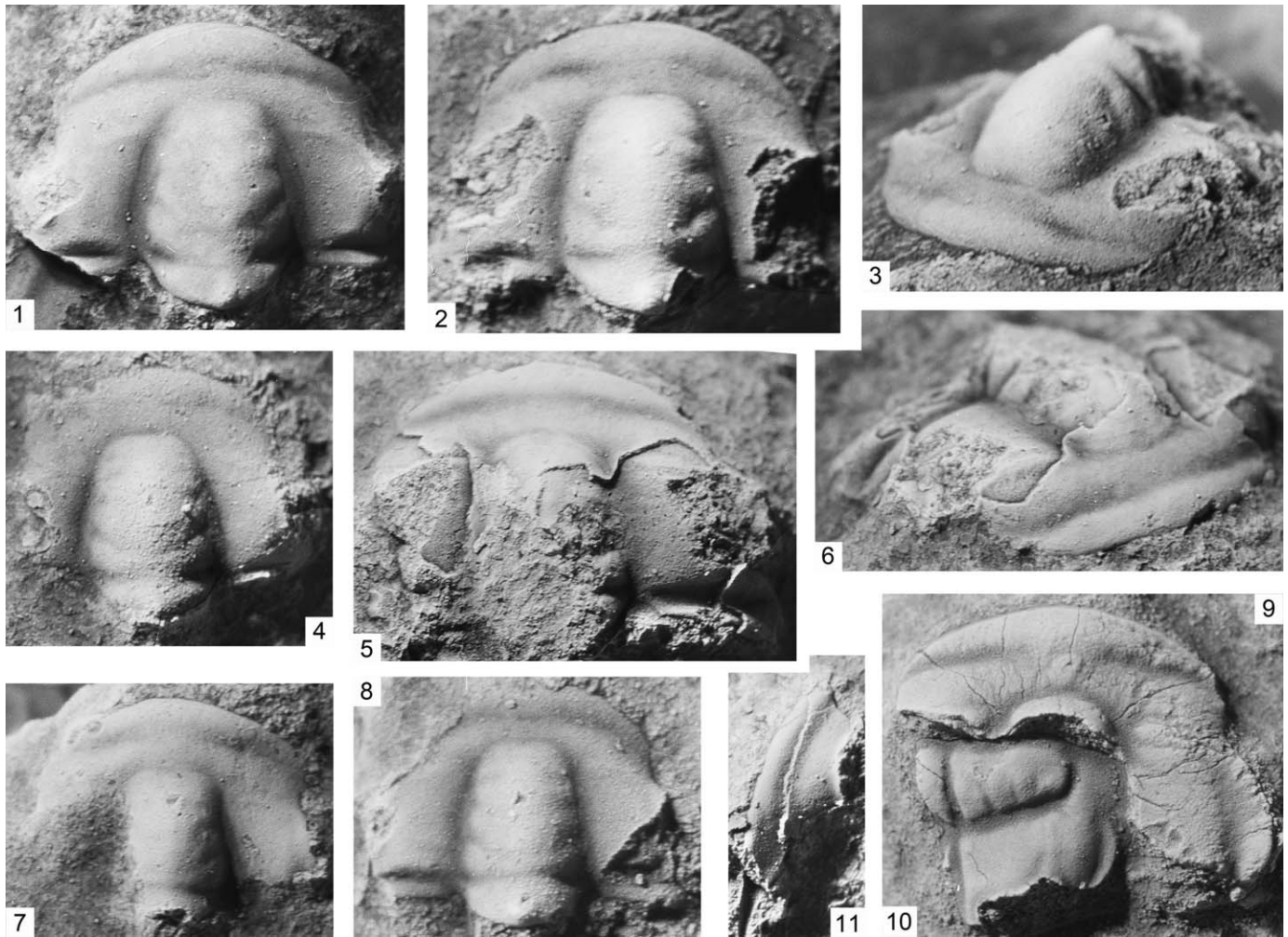


FIGURE 8—*Eokochaspis nodosa* Sundberg and McCollum, 2000 from the middle Cambrian Soldano Member, La Laja Formation, at Cerro El Molle, San Juan, Argentina (collections +20, +21 and +24 m): 1, cranidium (dorsal), IANIGLA-PI 571a, $\times 13.3$; 2, 3, cranidium (dorsal, anterior-oblique), IANIGLA-PI 572, $\times 12$; 4, cranidium (dorsal), IANIGLA-PI 575, $\times 15$; 5, 6, cranidium (dorsal, anterior-oblique), IANIGLA-PI 573, $\times 9$; 7, cranidium (dorsal), IANIGLA-PI 576, $\times 13.4$; 8, cranidium (dorsal), IANIGLA-PI 578, $\times 12.5$; 9, cranidium (dorsal), IANIGLA-PI 574a, $\times 10$; 10, cranidium (dorsal, rotated 90° to right), IANIGLA-PI 574b, $\times 10$; 11, free cheek (dorsal), IANIGLA-PI 577, $\times 10$.

smooth, unlike other species of *Hadrocephalites* (Sundberg and McCollum, 2002, fig. 11.1–11.4, 11.6–11.8).

Genus MEXICELLA Lochman, 1948

Type species.—*Mexicella mexicana* Lochman, 1948, from the Arrojos Formation (middle Cambrian) of northwestern Sonora, Mexico, by original designation.

Remarks.—*Mexicella* was erected for ptychoparioids, at the time placed in *Alokistocare* Lorenz, 1906, exhibiting a relatively short glabella, short palpebral lobe located just anterior to its preoccipital midpoint, wide, slightly downsloping fixed cheeks, and a wide convexity of the frontal area (see also Sundberg, 2004, p. 926). This inflation is not expressed in meraspides and early holaspides, however. The free cheek of the type species lacks a genal spine. Sundberg (2004) considered *Mexicella* to comprise a clade closely related to the informal ‘kochaspid’ group.

Five species have been named in addition to the type species: *M. stator* (Walcott, 1916a), *M. grandoculus* Palmer in Palmer and Halley, 1979, *M. granulata* Eddy and McCollum, 1997, *M. robusta* Sundberg and McCollum, 2000, *M. antelopea* Sundberg and McCollum, 2000, and *M. obscurus* (Palmer in Palmer and Halley, 1979) (see Sundberg, 2004, p. 928; =*M. obscura* nomen correctum). *Mexicella stator* was originally described from the

Cathedral Formation, southern Rocky Mountains of Canada (Rasetti, 1951, p. 231); all the rest are found in the southwestern part of the Great Basin. The first three occur in the traditional *Albertella* Biozone. By contrast, *M. antelopea* and *M. robusta* occur in older strata, in the *Eokochaspis nodosa* and overlying *Amecephalus arrosensis* biozones respectively, comprising the lower part of the traditional *Plagiura–Poliella* Biozone (Sundberg and McCollum, 2000).

Mexicella stator was distinguished from the type species by reduced convexity of the glabella, more even inflation of the preglabellar field rather than as a mostly median convexity, and possibly a slightly wider fixed cheek (Lochman, 1948, p. 458; Lochman in Cooper et al., 1952, p. 152). *Mexicella grandoculus* exhibits a slightly longer palpebral lobe, reaching half the preoccipital length of the glabella (Palmer in Palmer and Halley, 1979, p. 109). *Mexicella granulata* has densely granulate cranidial prosopon. The palpebral lobes are said to be more posteriorly located, and the anterior margin of the cranidium less evenly rounded, i.e. the poorly defined anterior border is slightly longer medially (Eddy and McCollum, 1997, p. 879). *Mexicella antelopea* is the only species bearing a genal spine, which is relatively short and narrow.

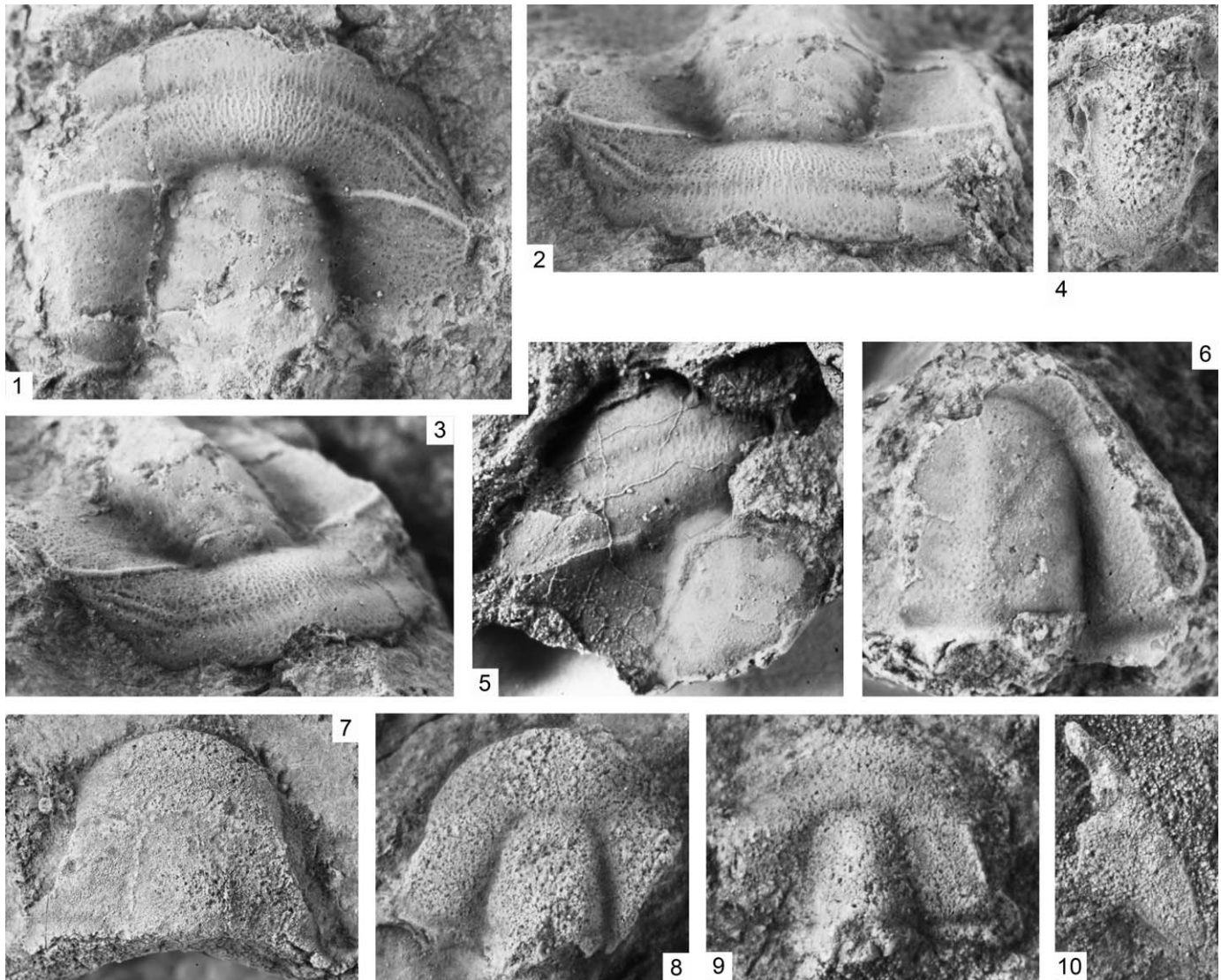


FIGURE 9—*Mexicella mexicana* Lochman, 1948 from the middle Cambrian Soldano Member, La Laja Formation, at Cerro El Molle, San Juan, Argentina (collection +48–50 m): 1–3, cranidium (dorsal, anterior, anterior-oblique), IANIGLA-PI 1371a, $\times 10$; 4, pygidium (dorsal; weathered axis), IANIGLA-PI 1376a, $\times 7$; 5, cranidium (dorsal; latex cast), IANIGLA-PI 1385, $\times 11$; 6, cranidium (dorsal), IANIGLA-PI 1375, $\times 13$; 7, cranidium (dorsal, weathered), IANIGLA-PI 1374a, $\times 5.5$; 8, cranidium (dorsal, weathered), IANIGLA-PI 1384a, $\times 10$; 9, cranidium (dorsal, weathered), IANIGLA-PI 1383, $\times 13.5$; 10, free cheek (dorsal, weathered), IANIGLA-PI 1386e, $\times 11.5$.

The various differences that have been used to distinguish species of *Mexicella* are not strongly contrasting. For example, cranidia assigned to the type species by Lochman (1948; in Cooper et al., 1952) show the palpebral lobe being usually anterior to the preoccipital glabellar midpoint, but in some cases is opposite to it, as it is in cranidia of *M. granulata*. Similarly, the width of the fixed cheek varies somewhat with respect to the preoccipital length of the glabella, and the convexity is also somewhat variable; the anterior facial suture also ranges from slightly divergent to slightly convergent. The original material of *M. mexicana* exhibits prosopon of dispersed granules, whereas these are absent in the cranidia assigned to this species by Palmer (in Palmer and Halley, 1979). Instead, *M. mexicana* from the Carrara Formation of southern Nevada and adjacent California are often densely pitted, as are well-preserved specimens from the Soldano Member. On the other hand, the preglabellar field of cranidia from the Arrojos and Carrara formations and Soldano Member are caecate. All described species appear to exhibit some variation in the degree of effacement of the dorsal furrows. A

better understanding of intraspecific variation within this group is necessary.

MEXICELLA MEXICANA Lochman, 1948
Figure 9.1–9.10

- 1948 *Mexicella mexicana* LOCHMAN, p. 457, pl. 69, figs. 12–17, 19–22 [non fig. 18].
1952 *Mexicella mexicana*; LOCHMAN in Cooper et al., p. 150, pl. 24, figs. 1–21, 23–25 [non Fig. 22].
1979 *Mexicella mexicana*; PALMER in Palmer and Halley, p. 109, pl. 13, figs. 13–21.
1998 *Mexicella mexicana*; EDDY AND MCCOLLUM, figs. 3, 4 [range charts].

Holotype.—Cranidium (USNM 115807) (Lochman, 1948, pl. 69, figs. 12–14; Lochman in Cooper et al., 1952, pl. 24, figs. 3–5).

Material.—Twenty-three (23) holaspid cranidia and cranidium fragments (IANIGLA-PI 1371a, b, 1372, 1373, 1374a, b, 1375, 1376b, 1377–1381, 1382a, b, 1383, 1384a, b, 1385, 1386a–d), one

pygidial fragment (IANIGLA-PI 1376a) and one free cheek (IANIGLA-PI 1386e).

Occurrence.—Rubbly weathering, thin-bedded argillaceous lime mudstones 48–50 m above base of Soldano Member, La Laja Formation, Cerro El Molle, San Juan (*Mexicella mexicana* Biozone); Arrojos Formation, northwestern Sonora (*Mexicella mexicana* Biozone); Carrara Formation, southwestern Nevada and adjacent California (*Mexicella mexicana* Biozone); Grassy Spring Member, Pioche Shale, southeastern Nevada (*Mexicella mexicana* Biozone).

Remarks.—Variably preserved specimens are assigned to this species on the basis of the slightly downsloping fixed cheek and preglabellar field, comparatively convex glabella, medially inflated preglabellar field bearing caeca, and absence of a genal spine. The pygidial fragment assigned to this species shows a slightly less strongly tapering axis compared to the one attributed to it by Lochman (1948, pl. 69, fig. 17; *in* Cooper et al., 1952, pl. 24, fig. 13).

Palmer (*in* Palmer and Halley, 1979) noted that the free cheek originally attributed to this species by Lochman (1948, pl. 69, fig. 18; Lochman *in* Cooper et al., 1952, pl. 24, fig. 22) is in error, as its well-defined flat border and long palpebral lobe do not match the cranial suture, unlike the free cheeks that are reliably assigned (Fig. 9.10; Lochman *in* Cooper et al., 1952, pl. 24, fig. 24; Palmer *in* Palmer and Halley, pl. 13, figs. 13, 17, 21).

PTYCHOBABA new genus

Type species.—*Ptychoparella buttsi* Resser, 1938b, designated herein.

Diagnosis.—Genus of Ptychopariidae with cranidium in width twice that of length. Frontal area downsloping, divided equally by anterior border furrow into preglabellar field and anterior border, usually with shallow median depression in former and gentle median swelling in latter. Anterior course of facial suture gently divergent. Glabella subquadrate in outline with anterior lobe gently rounded to transverse, bearing three pairs of shallow lateral glabellar furrows. Occipital node or spine absent. Fixed cheek gently convex, in width about half that of preoccipital glabella, crossed by prominent ocular ridge. Genal spine of moderate length. Thorax of 15 segments. Pygidium micropygous, transversely elliptical in outline.

Etymology.—For Loren E. Babcock.

Remarks.—The type species of *Ptychoparella* Poulsen, 1927, *P. brevicauda* Poulsen, 1927, was collected from boulders now known to come from the *Glossopleura* Biozone of the Cape Wood Formation of Inglefield Land, northwestern Greenland (Poulsen, 1964; Peel and Christie, 1982). *Syspacephalus* Resser, 1936, *Elrathina* Resser, 1937 and *Eoptychoparia* Rasetti, 1955 have been considered junior synonyms (Blaker and Peel, 1997, p. 124; Robison and Babcock, 2011, p. 27). On the other hand, Geyer and Peel (2011, p. 518) preferred to retain *Eoptychoparia*, noting morphological variation exhibited by specimens of *E. pearylandica* Geyer and Peel, 2011 in the Henson Gletscher Formation of North Greenland. They provisionally re-assigned *Ptychoparella* sp. A of Blaker and Peel (1997) to *Onchocephalus* Resser, 1937. Species belonging to *Ptychoparella* sensu lato have distinctly convex cranidia, convergent facial sutures, anteriorly rounded and somewhat inflated glabellae, fixed cheeks that are in width about half that of the glabella, short palpebral lobes, and genal spines are either short or absent (e.g., Poulsen, 1927, pl. 17, fig. 26; Blaker and Peel, 1997, figs. 73.1–73.10, 76.1–76.4, 77.1–77.4, 77.7, 77.8; Robison and Babcock, 2011, figs. 19.1, 19.7, 19.19, 20.1–20.4). They range from upper lower Cambrian (series 2, stage 4, Dyeran stage of Laurentia) to middle Cambrian (series 3, Drumian stage). Robison and Babcock (2011) considered *Ptychoparella* to belong to Lonchocephalidae.

Resser (1938a) placed five species, plus one with question, in *Ptychoparella*. *Ptychoparella minor* from the lower Cambrian Shady Dolomite may conform to the genus (Resser, 1938b, pl. 3, fig. 18). However, *P. lancastra* from the lower Cambrian Kinzers Formation of Pennsylvania has a tapering glabella and long frontal area, similar to the cranidium of *Kochiella? pennsylvanica* Resser, 1938b from the same formation (Resser, 1938b, pl. 3, figs. 13, 16, 17), and thus is likely unrelated.

Ptychoparella buttsi Resser, 1938b and *P. michaeli* Resser, 1938b are based on complete exoskeletons each with 15 segments (not 16 in *P. michaeli* as stated by Resser). The free cheeks are wider than those of other species of *Ptychoparella* and consequently their cranidia are broader. The glabella is subquadrate in outline and the palpebral lobes are longer. The facial sutures diverge slightly rather than converge. A new genus is warranted for these.

These two species are stated to come from the lower Cambrian Rome Formation and Shady Dolomite, respectively, of southern Virginia. The former is represented by weathered molds in very fine-grained sandstone while material belonging to the latter is compressed and decalcified in weathered shale. These stratigraphic units interfinger with each other and extend into the earliest middle Cambrian before the Hawke Bay hiatus (Read and Repetski, 2012). Co-occurring with *P. buttsi* and *P. michaeli* in the same samples are sclerites provisionally identified as belonging respectively to *Mexicella stator* (Walcott, 1916a) and *Wenckhemnia* sp. both of which are known from the early middle Cambrian (Rasetti, 1951). Neither collection contains olenelloids.

PTYCHOBABA BUTTSI (Resser, 1938b)

Figures 10.1–10.8, 11.1–11.11

1938b *Ptychoparella buttsi* Resser, p. 97, pl. 5, fig. 3.

1938b *Ptychoparella michaeli* Resser, p. 97, pl. 6, fig. 16.

Holotype.—Complete exoskeleton (USNM 94771) (Resser, 1938b, pl. 5, fig. 3; Fig. 10.1–10.3 herein).

Description.—Exoskeleton is subovate in outline, with 15 thoracic segments and micropygous pygidium.

Cranidium is subrectangular in outline and moderately convex. Glabella is subtriangular to subquadrate in outline and well defined by axial furrows, with three pairs of shallow lateral glabellar furrows (not visible in sandstone molds in USNM 94771). Anterior course of facial suture is gently divergent. Downsloping preglabellar field is slightly longer than moderately short, convex anterior border and separated from it by relatively well-incised anterior border furrow; median swelling is present in the frontal area. Occipital ring possibly bears occipital node. Fixed cheek is gently convex and slightly downsloping, in width about half that of the preoccipital glabella, and crossed by well-defined, slightly obliquely oriented ocular ridge. Uprturned palpebral lobe is located opposite glabellar midlength and in length is 0.5–0.6 the length of the glabella. Free cheek has a well-defined, convex lateral border and bears a moderately short genal spine. Hypostome is unknown.

Thorax has well defined, gently posteriorly tapering axis; axial ring furrows are well incised. Pleurae are each crossed by well defined pleural furrow. Pleural spines are uniformly short.

Pygidium with short axis consisting of one or two axial rings and terminal piece defined by two or three shallow axial ring furrows. Pleural field is crossed by two or three shallow pleural furrows. Posterior border is short; border spines are absent.

Prosopon of cranidia is not evident in specimens from the Shady Dolomite and Rome Formation but is granulate in the Soldano Member. Glabella of meraspid cranidium from Soldano Member is quadrate in outline; short preglabellar field is concave,

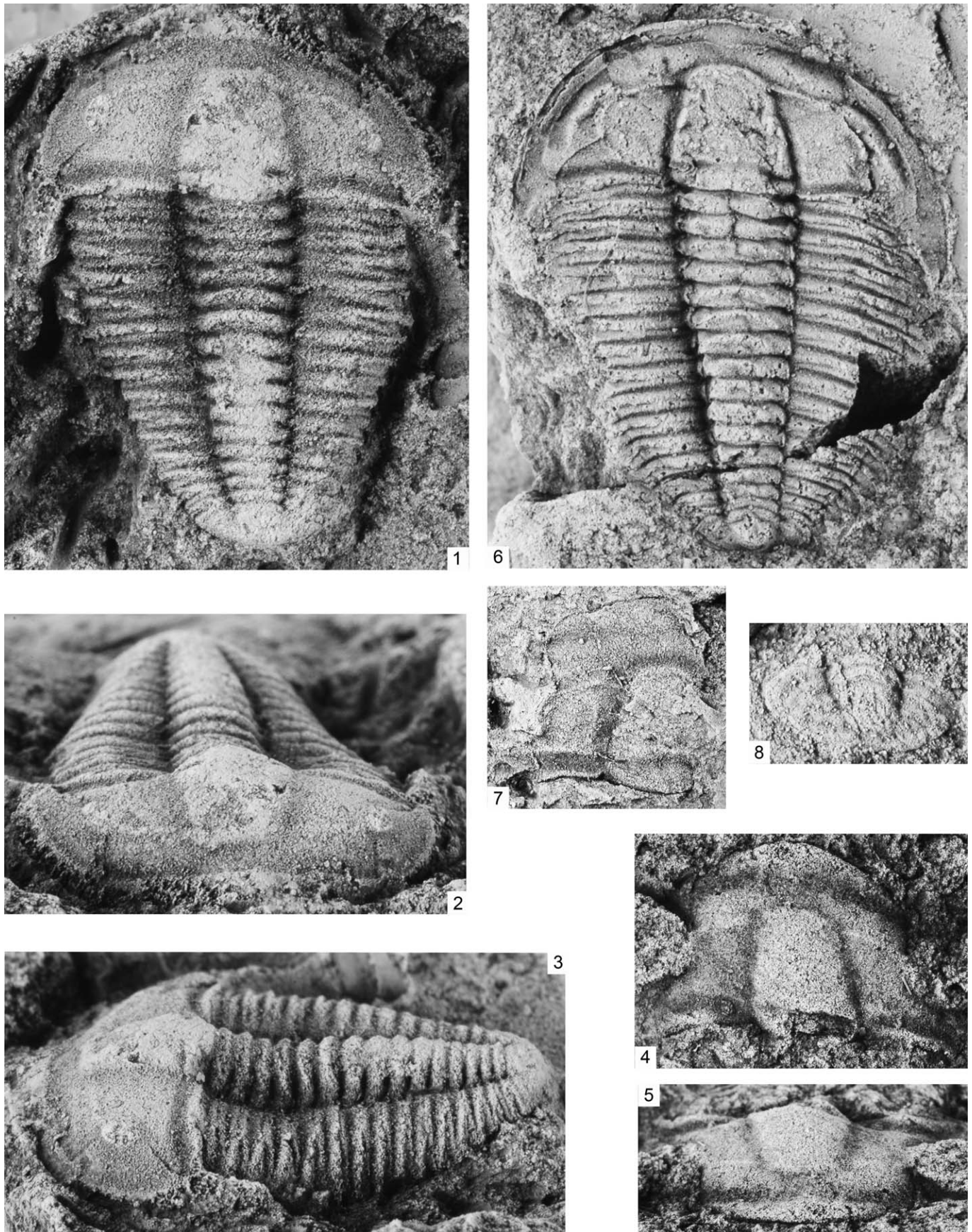


FIGURE 10—*Ptychobaba buttsi* (Resser, 1938b) from the lower to middle Cambrian Rome Formation, southwestern Virginia, U.S.A. (1–5, “Rome; 3.5 miles southwest of Buchanan”; 6–8 “Shady; 0.7 mile northwest of Bethany, near Austinville”): 1–3, complete exoskeleton (dorsal, anterior, lateral; in sandstone),

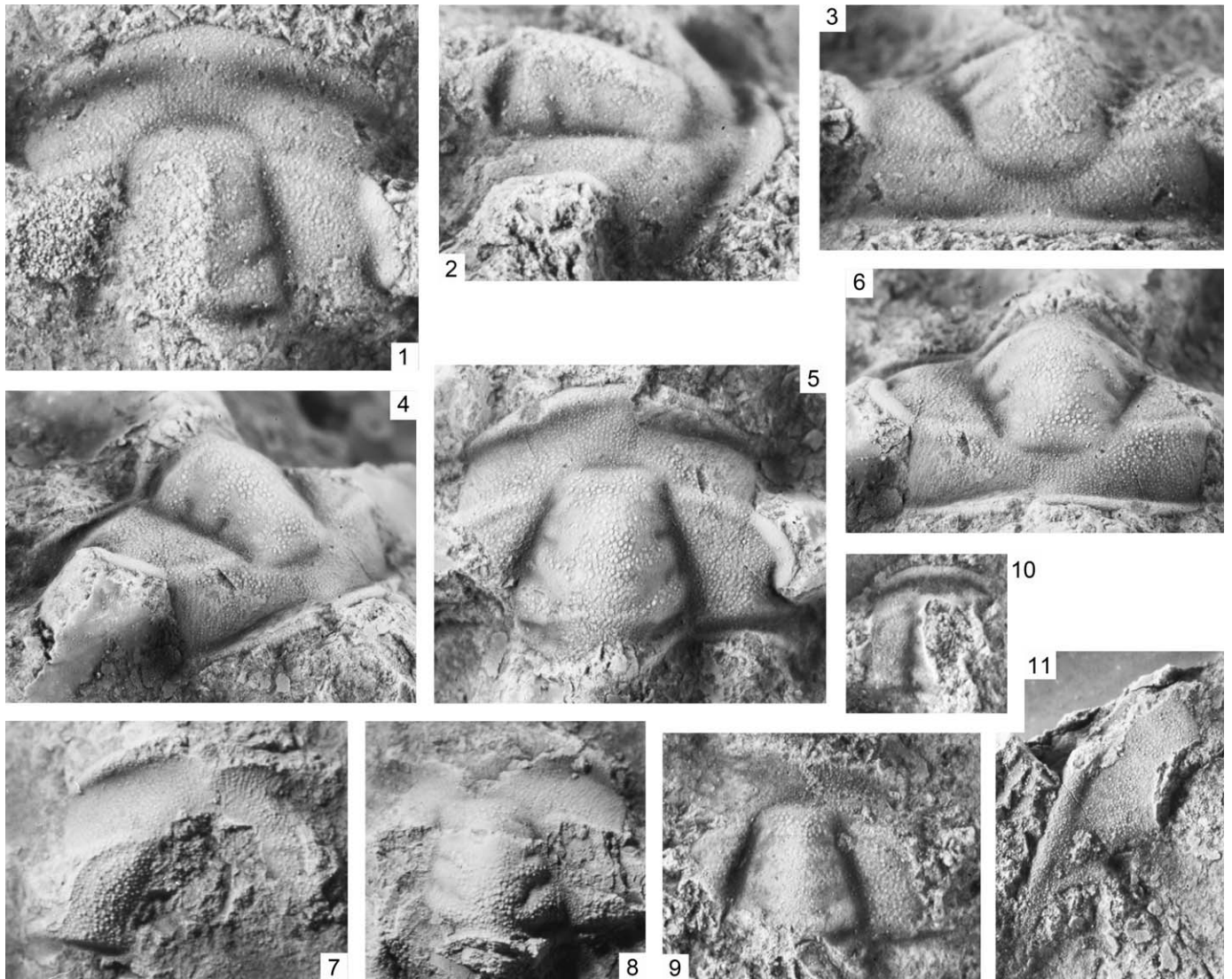


FIGURE 11—*Ptychobaba buttsi* (Resser, 1938b) from the middle Cambrian Soldano Member, La Laja Formation, at Cerro El Molle, San Juan, Argentina (1–3, 10 collection +1m; 4–6, 9, 11 collection +14 m; 7, 8 collection +10 m): 1–3, cranidium (dorsal, lateral, anterior), IANIGLA-PI 1357, $\times 12$; 4–6, cranidium (anterior-oblique, dorsal, anterior), IANIGLA-PI 1364a, $\times 7.5$; 7, cranidium (dorsal), IANIGLA-PI 582 $\times 8.5$; 8, cranidium (dorsal), IANIGLA-PI 583, $\times 10$; 9, cranidium, IANIGLA-PI 1365, $\times 9$; 10, meraspid cranidium (dorsal), IANIGLA-PI 1361, $\times 20$; 11, free cheek (dorsal), IANIGLA-PI 1366, $\times 8$.

equal in length to a short, convex anterior border. Hypostome, thoracic segments and pygidium were not recovered.

Material.—Ten (10) holaspid cranidia, one meraspid cranidium, and one free cheek (IANIGLA-PI 582, 583, 1357, 1361, 1364a, b, 1365–1370).

Occurrence.—Thin-bedded grainstones 1 m, 10 m and 14 m above base of Soldano Member, La Laja Formation, Cerro El Molle, San Juan (*Amecephalus arrojosensis*–*Eokochaspis nodosa* Biozone); Rome Formation and Shady Dolomite, southern Virginia (probably lower stage 5, *Plagiura*–*Poliella* Biozone equivalent).

Remarks.—Prosopon cannot be distinguished in *Ptychobaba buttsi* from Virginia likely due to poor preservation: specimens in USNM 94771 and USNM 94781 are molds in sandstone and shale respectively. It is also possible that granulate prosopon may be a

variable character in this species. Variation in the degree of granulation or tuberculation has been observed in some other Cambrian and Early Ordovician taxa (e.g., Taylor and Halley, 1974, p. 32; Pratt, 1992, p. 62; Elicki and Geyer, 2013, p. 18) and has been considered to reflect intraspecific differences in these cases.

In the holotype the anterior and lateral border of the cephalon is incomplete because the thin outer edge of the doublure not filled by sand was lost upon dissolution. The lateral glabellar furrows are not apparent in the Virginia specimens in sandstone but are present, albeit indistinctly, in those in shale.

Kochiella? gibbosa Rasetti, 1957 from the Mount Whyte Formation of the southern Rocky Mountains has a coarse granulate prosopon, and has a similar median swelling in the frontal area which is atypical for species of *Kochiella* (Sundberg

holotype of *Ptychoparella buttsi* Resser, 1938b (pl. 5, fig. 3), USNM 94771[a], $\times 7$; 4, 5, cranidium (dorsal, anterior), USNM 94771[b], $\times 6$; 6, complete exoskeleton (dorsal; in shale), holotype of *P. michaeli* Resser, 1938b (pl. 6, fig. 16), USNM 94781[a], $\times 9$; 7, cranidium (dorsal), USNM 94781[b], $\times 5$; 8, pygidium (dorsal; latex cast), USNM 94781[c], $\times 10$.

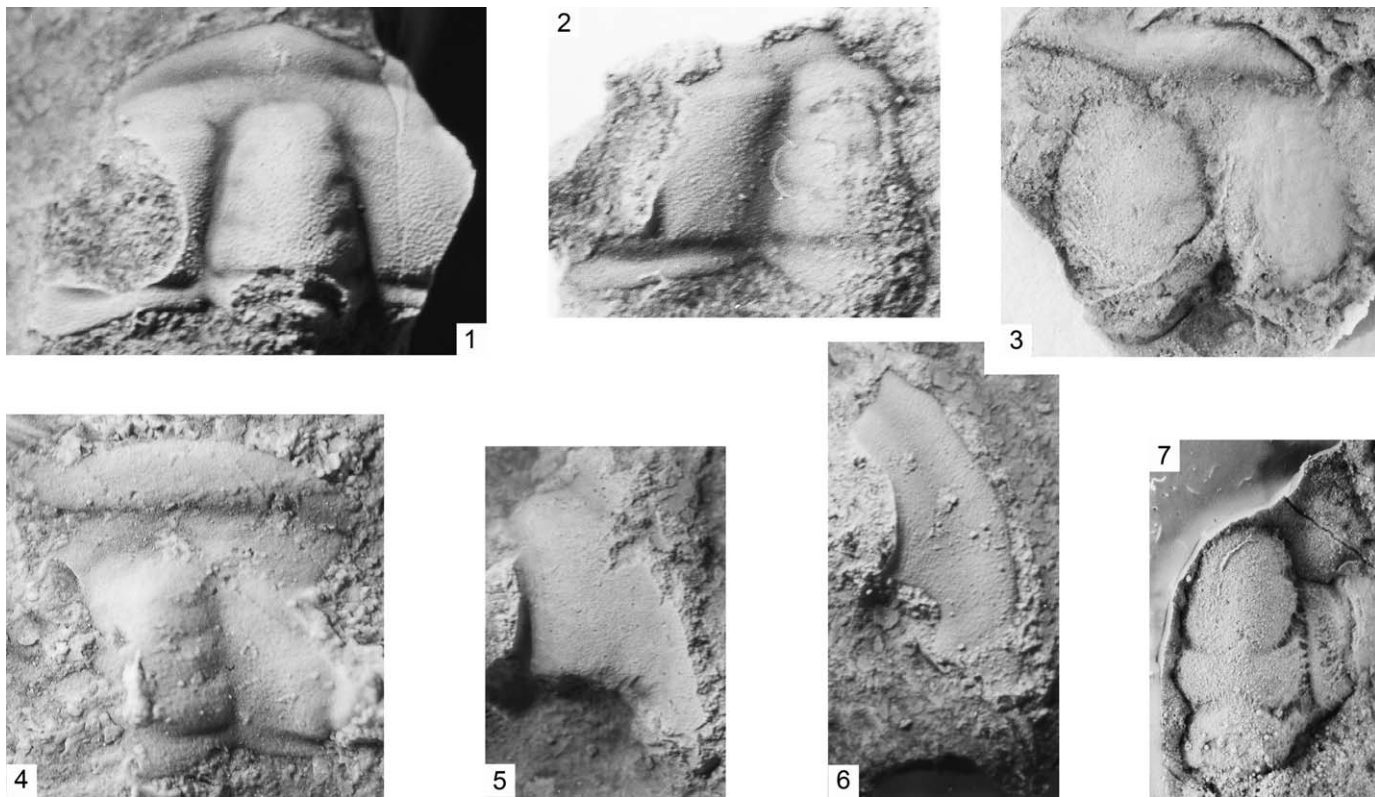


FIGURE 12—Miscellaneous trilobite sclerites from the middle Cambrian Soldano Member, La Laja Formation, at Cerro El Molle, San Juan, Argentina. 1, 2, *ptychoparioid* gen. and sp. indet. (collection +24 m): 1, cranidium (dorsal), IANIGLA-PI 580, $\times 14$; 2, cranidium (dorsal), IANIGLA-PI 581, $\times 12.5$; 3, *Hadrocephalites* sp. indet., cranidium (dorsal; latex cast), IANIGLA-PI 1376b, $\times 4.5$ (collection +48–50 m); 4, 5, *Kochiella* sp. indet. (collection +6 m): 4, cranidium, IANIGLA-PI 585, $\times 11$; 5, free cheek (dorsal), IANIGLA-PI 588, $\times 10$; 6, *Corynexochid* gen. and sp. indet. 2, free cheek (dorsal), IANIGLA-PI 571b, $\times 13.3$ (collection +24 m); 7, *Corynexochid* gen. and sp. indet. 1, cranidium (dorsal; latex cast), IANIGLA-PI 1372, $\times 10$ (collection +48–50 m).

and McCollum, 2002). Whereas the palpebral lobes are similar in length, the fixed cheek of *K. gibbosa* is wider, about two-thirds the width of the glabella (Rasetti, 1957, pl. 121, figs. 1–4) as opposed to one-half as in *P. buttsi*. As pointed out by Sundberg and McCollum (2002, p. 79), the pygidium is unknown for *K. gibbosa* which means it cannot be placed with certainty in *Kochiella*. It may be a second species of *Ptychobaba*, but differing from *P. buttsi* by the having a short occipital spine.

PTYCHOPARIOID genus and species indeterminate
Figure 12.1, 12.2

Material.—Two cranidia (IANIGLA-PI 580, 581).

Occurrence.—Thin-bedded grainstone 24 m above base of Soldano Member, La Laja Formation, Cerro El Molle, San Juan (*Amecephalus arrosensis*–*Eokochaspis nodosa* Biozone).

Remarks.—The two incomplete cranidia have a glabella that is subquadrate in outline with three pairs of lateral glabellar furrows. The palpebral lobe is posteriorly located and is in length two-thirds that of the preoccipital glabella; the broad, convex fixed cheek bears a relatively well-defined ocular ridge. The preglabellar field and gently convex anterior border are both comparatively short. The anterior border in one specimen (Fig. 12.1) tapers laterally and exhibits a slight median swelling. The occipital ring appears to lack a median node; prosopon is finely granulate.

These cranidia differ from those in the same collection assigned to *Eokochaspis nodosa* in having a straight-sided glabella, longer and posteriorly located palpebral lobe, granulate prosopon, and no occipital node. It is somewhat similar to *Ptychobaba buttsi* which

occurs in older strata, but the fixed cheek is wider and more convex.

Order CORYNEXOCHIDA Kobayashi 1935
CORYNEXOCHID genus and species indeterminate 1
Figure 12.7

Material.—One cranidium (IANIGLA-PI 1372).

Occurrence.—Rubbly weathering, thin-bedded argillaceous lime mudstones 48–50 m above base of Soldano Member, La Laja Formation, Cerro El Molle, San Juan (*Mexicella mexicana* Biozone).

Remarks.—The single fragmentary cranidium exhibits an anteriorly gently tapering glabella, narrow fixed cheek, and a relatively short palpebral lobe located opposite the preoccipital glabellar midlength. Species belonging to several early middle Cambrian dolichometopid and zacanthoidid genera have a somewhat similar cranidium, such as *Poliella* cf. *P. prima* Walcott, 1916b (Sundberg and McCollum, 2003a, fig. 10.8, 10.9), *Poliellaites gloriosa* Sundberg and McCollum, 2003a (fig. 9.1, 9.2), *Dolichometopsis?* sp. undet. (Rasetti, 1957, pl. 118, figs. 9–13), and *Albertella fritzi* Eddy and McCollum, 1998 (fig. 5.14, 5.15).

CORYNEXOCHID genus and species indeterminate 2
Figure 12.6

Material.—One free cheek (IANIGLA-PI 571b).

Occurrence.—Thin-bedded grainstone 24 m above base of Soldano Member, La Laja Formation, Cerro El Molle, San Juan (*Amecephalus arrosensis*–*Eokochaspis nodosa* Biozone).

Remarks.—The single free cheek has a narrow genal field, a long circumocular suture, and a short narrow genal spine. The

shape of the posterior suture suggests it belongs to a comparatively narrow cranidium like that belonging to *Albertella*. However, the short genal spine is atypical if not unreported for early middle Cambrian dolichometopid and zacanthoidid genera.

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