

Small shelly fossils from the Montezuman–Delamaran of the Great Basin in Nevada and California

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Abstract.—The mixed carbonate-siliciclastic successions of the Cambrian Series 2–Cambrian Series 3 interval of the Great Basin are well investigated in respect to their trilobite and brachiopod fauna. In contrast, the small shelly fossils have been mostly unreported. Nine sections in eastern California and southern Nevada have produced a small shelly assemblage of low diversity, which likely reflects non-phosphatization and loss of originally calcareous remains. From the Montezuman–Delamaran stages we report *Anabarella chelata* Skovsted, 2006a, *Costipelagiella nevadense* Skovsted, 2006a, *Pelagiella* aff. *P. subangulata* (Tate, 1892), *Microcornus* sp., *Parkula* sp., *Hyolithellus?* sp., *Allonia* sp., *Chancelloria* sp., *Archiasterella* cf. *A. hirundo* Bengtson in Bengtson et al., 1990, *Archaeooides* cf. *A. granulatus* Qian, 1977, and undefined echinoderms and helcionelloid molluscs. The lower part of the Montezuman Stage delivered a number of lobopodian sclerites as *Microdictyon rhomboidale* Bengtson, Matthews, and Missarzhevsky, 1986, *Microdictyon montezumaensis* n. sp., and *Microdictyon cuneum* n. sp. The occurrence of *P.* aff. *P. subangulata* and species of *Microdictyon* in the lower Montezuman Stage offers a fundamental potential for correlation with the base of Cambrian Series 2/Stage 3 of South China, Siberia, and Avalonia.

Introduction

The Great Basin of western United States contains the most complete and well-exposed sections covering the Cambrian Series 2–Series 3 interval (Montezuman–Marjuman stages of the Laurentian nomenclature; Palmer, 1998). These highly fossiliferous, mixed carbonate-siliciclastic successions have been extensively investigated for their trilobite and brachiopod faunas (e.g., Rowell 1966, 1977, 1980; Rowell and Henderson, 1978; Palmer and Halley, 1979; Sundberg and McCollum, 1997, 2000, 2003a, b; Hollingsworth 2005, 2011a, b; Streng and Holmer, 2006; Sundberg, 2011; Webster, 2011a). However, other faunal elements, especially small shelly fossils (SSFs), are generally unconsidered. These SSFs provide important information for biostratigraphic, depositional environment, and paleoecologic reconstructions (e.g., Geyer, 1986; Elicki, 1994, 2005, 2006; Geyer and Shergold, 2000; Gubanov, 2002; Steiner et al., 2007).

Few, non-brachiopod, SSFs have been reported in detail from the Great Basin. Tubes of uncertain affinity and the hyolith *Salanytheca* sp. occur in the pre-trilobitic Cambrian Deep Spring Formation of western Nevada and eastern California (Signor et al., 1987). The agglutinated protist *Platysolenites antiquissimus* Eichwald, 1860, chancelloriid sclerites, helioplacoid ossicles, and hyoliths occur in the Montezuman Stage of Indian Springs Canyon (Fig. 1; Streng et al., 2005; English and Babcock, 2010). *Hyolithellus insolitus* Grigorieva in Voronin et al., 1982, *Sphenotallus* sp., echinoderm ossicles, and sponge spicules were described from the lower Dyeran Harkless Formation of Gold Point (Fig. 1; Skovsted and Holmer, 2006).

Furthermore, the helcionelloid molluscs *Anabarella chelata* Skovsted, 2006a and *Costipelagiella nevadense* Skovsted, 2006a, the hyolith *Parkula esmeraldina* Skovsted, 2006a, and remains of echinoderms, chancelloriids, and sponges occur in the uppermost Dyeran Stage from the basal Emigrant Formation of Split Mountain (Fig. 1; Skovsted, 2006a). The lower Cambrian hyolith fauna originally described by Walcott (1886) and Resser (1938) from Nevada were reinvestigated by Malinky (1988).

Most recent report of SSFs from the Great Basin only mentioned their presence without any illustration, systematic documentation, and/or detailed stratigraphic distribution. Hollingsworth (2011b) and Hollingsworth and Babcock (2011) reported the hyolith “*Ladatheca*” *cylindrica* Grabau, 1900, orthothecid hyoliths, and the bradoriid *Dielymella?* Ulrich and Bassler, 1931 from the Montezuman Stage and the lower unnamed stage of the Indian Springs Canyon and Montezuma Range sections (Fig. 1). Webster (2011c) mentioned pelagiellids, hyoliths, and chancelloriids from the upper Dyeran from a variety of sections in Nevada. Sundberg and McCollum (1997, 2003a) and McCollum et al. (2011) mentioned *Stenothecoides elongata* Walcott (1886) and *Latouchella arguta* Resser (1939) and hyoliths, echinoderms, and chancelloriids from the lower Delamaran Stage of Nevada.

The purpose of this report is to document a new small shelly assemblage from a variety of Montezuman–Delamaran mixed carbonate-siliciclastic successions of eastern California and southern Nevada in order to increase the knowledge of the paleogeographic and biostratigraphic potential of these faunal elements.

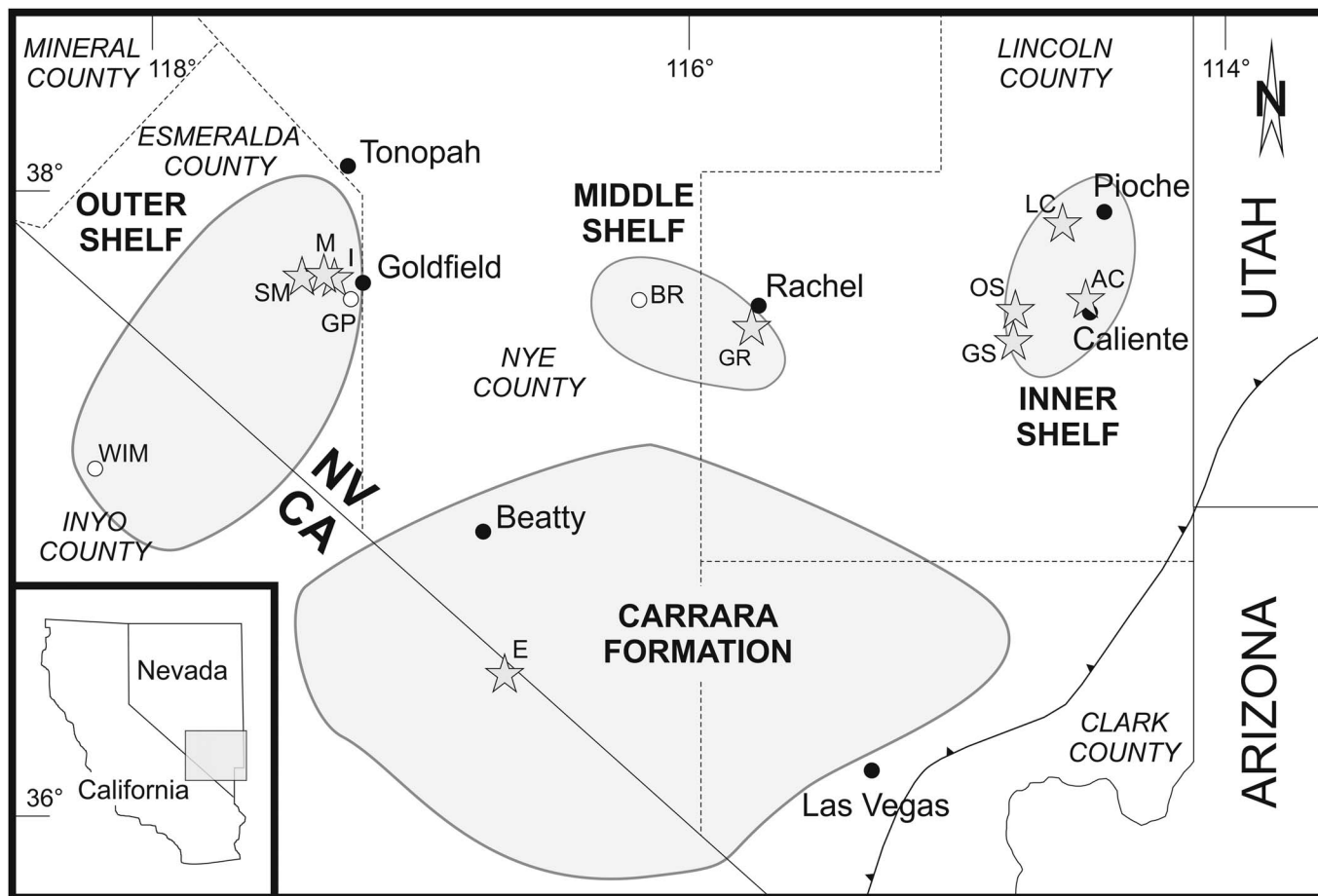


Figure 1. Map of the southern Great Basin, showing the facies realms of the inner, middle, and outer shelf (modified from Palmer and Halley, 1979; Sundberg and McCollum, 2000, 2003a; McCollum and McCollum, 2011; Sundberg, 2011; Webster, 2011a). Shaded stars mark the sections investigated: AC, Antelope Canyon; E, Echo Canyon; GR, Groom Range; GS, Grassy Spring; I, Indian Springs Canyon; LC, Log Cabin Mine; M, Montezuma Range; OS, Oak Spring Summit; SM, Split Mountain. White circles represent localities mentioned in the text: BR, Belted Range; GP, Gold Point; WIM, White-Inyo Mountains.

General geology and stratigraphy

The Montezuman–Delamaran succession of the Great Basin reflects the overall flooding of the western margin of the Laurentian craton (Webster, 2011a). During this time the shelf was spatially and temporally heterogeneous, as documented by the multitude of regional lithostratigraphic units (e.g., Palmer and Halley, 1979; Sundberg and McCollum, 2003b; Webster, 2011a, b; Figs. 1, 2). Based on lithofacies and trilobite distribution patterns, the depositional environment is separated into inner, middle, and outer shelf facies realms (e.g., Stewart, 1970; Palmer and Halley, 1979; Sundberg and McCollum, 2003a; McCollum and McCollum, 2011; Sundberg, 2011; Webster, 2011a; Figs. 1, 2).

Inner shelf facies.—Sections of the inner shelf facies are primarily exposed in the Pioche–Caliente area of eastern Nevada (Fig. 1). The Dyeran–Delamaran boundary interval is represented by the Pioche Formation (*Arcuolenellus arcuatus*–*Mexicella mexicana* zones; Sundberg and McCollum, 2000; Sundberg, 2011; Webster, 2011a, c; Fig. 2). Its lower part, the Delamar Member, consists of a succession of bioturbated claystone and

siltstone interbedded with sandstone and conglomerate layers, with carbonate intercalations at the top (Webster, 2011c). The lower cliff-forming portion of the succeeding Combined Metals Member consists of bioclastic oncolitic limestone, nodular limestone, and thin limestone beds. The upper portion of the Combined Metals Member shows a higher siliciclastic content, represented by ribbon limestone, nodular limestone, siltstone, and sandstone intercalations (Webster, 2011c). The base of the Delamaran starts with the Comet Shale Member (*Eokochaspis nodosa*–*Amecephalus arrojensis* zones; Fig. 2), predominated by claystone and siltstone with a few thin limestone beds (Sundberg and McCollum, 2000; McCollum and McCollum, 2011). It is disconformably overlain by the Susan Duster Limestone Member (*Amecephalus arrojensis*–*Poliella denticulata* zones), which consists of a basal bioclastic limestone, an interval of claystone and nodular limestone, and an upper part of nodular-bedded limestone (Sundberg and McCollum, 2003b; Sundberg, 2011). The overlying Log Cabin Member (*Poliella denticulata* Zone) consists of claystone and siltstone with intercalations of sandstone and bioclastic limestone (Sundberg and McCollum, 2003b; McCollum and McCollum, 2011; Sundberg, 2011). The uppermost part of the Pioche Formation is represented by the Grassy Spring Member

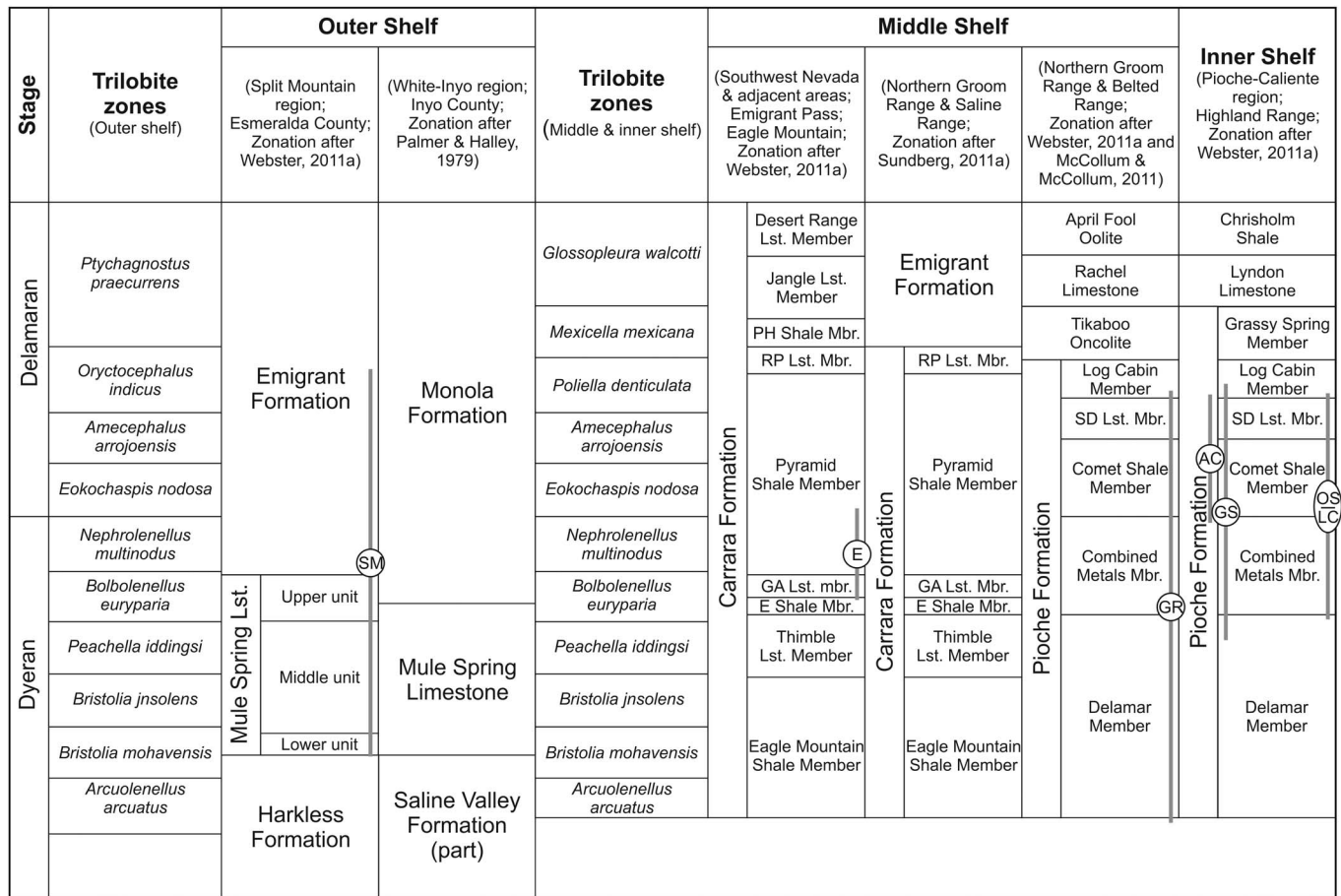


Figure 2. Biostratigraphic zonation of the upper Dyeran–Delamaran interval, and associated lithostratigraphy on the outer, middle, and open shelf of Nevada and SE-California, western Laurentia (modified from Palmer and Halley, 1979; Sundberg and McCollum, 2000, 2003b; McCollum and McCollum, 2011; Sundberg, 2011; Webster, 2011a). Stratigraphic positions of the analyzed Dyeran–Delamaran sections are marked. Abbreviations: E Shale Mbr., Echo Shale Member; GA Lst. Mbr., Gold Ace Limestone Member; PH Shale Mbr., Pahrump Hills Shale Member; RP Lst. Mbr., Red Pass Limestone Member; SD Lst. Mbr., Susan Duster Limestone Member; Lst., limestone; Mbr., member. See Figure 1 for section abbreviations.

(*Mexicella mexicana* Zone) consisting of claystone, siltstone, and sandstone (Eddy and McCollum, 1998; McCollum and McCollum, 2011; Sundberg, 2011).

Middle shelf facies.—The Dyeran–Delamaran of the middle shelf facies is represented by the Carrara Formation in southern Nevada and southeastern California (Fig. 1). The Carrara Formation is separated into nine siliciclastic and carbonate intervals, ranging from the *Arcuolenellus arcuatus* Zone to the *Glossopleura walcotti* Zone (Palmer and Halley, 1979; Webster, 2011a; Fig. 2). The lowermost and uppermost carbonate members (Thimble Limestone and Desert Range Limestone members, respectively) are characterized by thin-bedded argillaceous (dolomitic) limestone (Palmer and Halley, 1979). In contrast, the other limestone portions are cliff-forming units, composed of oncolitic, oolitic, laminated, and fenestral limestone (Palmer and Halley, 1979). The lithostratigraphic nomenclature applied by Palmer and Halley (1979) does not fit with the sedimentary succession observed in the northern Groom Range and Belted Range (GR and BR in Fig. 1) of central Nevada, which resulted in several synonymous nomenclatures for the region (Fig. 2; McCollum and McCollum, 2011; Sundberg, 2011; Webster, 2011a; Webster et al., 2011).

Outer shelf facies.—Sections of the outer shelf facies crop out in western Nevada and eastern California (Fig. 1). The Dyeran Mule Spring Limestone is represented by predominately shallow subtidal–intertidal carbonates and is subdivided into: (1) a lower unit, composed of cliff-forming bioturbated limestone; (2) a middle unit, composed of bioclastic, oncolitic, oolitic, and peloidal limestones with numerous claystone intercalations; and (3) an upper cliff-forming unit composed of oncolitic and fenestral limestones with intercalated intraformational conglomerates (Fig. 2; Nelson, 1962; Stewart, 1970; Albers and Stewart, 1972; Webster, 2011a, b). The Mule Spring Limestone is overlain by the siliciclastic and carbonate, partly highly condensed Emigrant Formation (uppermost Dyeran–Sunwaptan Stage) in western Nevada and by the Monola Formation in Death Valley National Park of eastern California (e.g., Palmer, 1971; Palmer and Halley, 1979; McCollum and McCollum, 2011; Sundberg, 2011; Sundberg et al., 2011). The Monola Formation is subdivided into a lower claystone portion with intercalated limestone and an upper limestone with minor siltstone intercalations (Sundberg and McCollum, 1997). McCollum and McCollum (2011) identified the depositional environment of the Monola Formation as located between the outer shelf position of the Emigrant Formation and the medial to inner shelf positions of the Carrara and Pioche formations.

Materials and methods

The material described in this report derives from nine sections covering the Montezuman–Delamaran interval (Terreneuvian/Cambrian Stage 2–Cambrian Series 3/Cambrian Stage 5) of the different shelf facies realms (Figs. 1–4). All carbonate samples are characterized by a high fossil content observable in thin sections or even macroscopically. However, the major part of small shelly fossils is preserved as carbonate, which hampers extraction from the limestone. Several preparation methods were tested using 95% to pure acetic acid partly in combination with copper(II) sulfate and chloroform (see Nötzold, 1965; Knitter, 1979; Tarsilli and Warne, 1997). All these methods require a distinct porosity of the limestone that enables the intrusion of chemicals and thus the expansion of the rock due to gassing or crystallization. But, the Laurentian samples are strongly lithified without any porosity, which inhibited extraction of microfossils using these procedures. The best results were realized by dissolving the carbonate samples in buffered 7% acetic acid. The extracted microfossils are often corroded during the chemical preparation, but it seems to be the only way for releasing a significant number of small shelly fossils from the Laurentian samples. However, due to dissolution of a majority of the carbonate fossils, this procedure delivered only few phosphatic internal molds and silicified specimens out of the total fossil content. Acetic residues were sieved, dried, and the faunal elements were hand-picked from the residue under a binocular microscope. Subsequently, they were mounted, sputter-coated with gold, and photographed under a CamScan 44 scanning electron microscope at the Department of Geology of the University of Cologne.

Repositories and institutional abbreviations.—The material described and figured is housed in the collection of the Geological Institute of the TU Bergakademie Freiberg under the prefix FG 544/GB/locality/sample/SEM-stub number. For brevity herein, localities and specimens are cited without the prefix FG 544/GB. Localities are listed as AC (Antelope Canyon), E (Echo Canyon), GR (Groom Range), GS (Grassy Spring), I (Indian Springs Canyon), LC (Log Cabin Mine), M (Montezuma Range), OS (Oak Spring Summit), and SM (Split Mountain) (Figs. 1–4). Individual collections are denoted by locality abbreviation and sample number (e.g., SM 14).

Systematic paleontology

The helcionelloid molluscs, *Anabarella chelata* and *Costipelagiella nevadense*, were verified from the lowermost Emigrant Formation of the Split Mountain section (SM 14, SM 15; Fig. 3). Stratigraphic position and locality are identical with those published by Skovsted (2006a). Thus, these species are figured (Fig. 5.1–5.16), but not discussed herein.

Phylum Mollusca Cuvier, 1797
 Class Helcionelloida Peel, 1991
 Order Helcionellida Geyer, 1994
 Family Helcionellidae Wenz, 1938
 Genus *Pelagiella* Matthew, 1895

Type species.—*Cyrtolithes atlantoides* Matthew, 1894; lower Cambrian of southeast New Brunswick, Canada.

Pelagiella aff. *P. subangulata* (Tate, 1892)
 Figures 5.17–5.22, 6.1–6.23, 7.1–7.6, 8.35–8.37

- 1892 *Ophileta subangulata* Tate, p. 184, pl. 2, fig. 8a–b.
 1984 *Pelagiella emeishanensis* He in Xing et al., p. 167, pl. 13, figs. 1–5.
 1986 *Pelagiella* sp.; Laurie, p. 447, fig. 10D–E.
 1990 *Pelagiella subangulata*; Runnegar in Bengtson et al., p. 254, figs. 167, 168A–D, 169A–F, H–L.
 1994 *Pelagiella emeishanensis*; Elicki, p. 71, fig. 4.8.
 1994 *Pelagiella lorenzi* Kobayashi, 1939; Elicki, p. 71, fig. 4.6, 4.7.
 1996 *Pelagiella emeishanensis*; Elicki, p. 155, pl. 7, figs. 6, 7.
 1996 *Pelagiella lorenzi*; Elicki, p. 154, pl. 7, figs. 1–5.
 1996 ?*Pelagiella* aff. *adunca* He and Pei in He, Pei, and Fu; Elicki, p. 155, pl. 8, figs. 1–4.
 1996 ?*Pelagiella* sp.; Elicki, p. 156, pl. 8, figs. 5–8.
 2001 *Pelagiella subangulata*; Parkhaev in Gravestock et al., p. 193, pl. 44, figs. 1–14, pl. 45, figs. 1–10.
 2002 *Pelagiella subangulata*; Elicki, p. 23, pl. 1, figs. 1–18.
 2003 *Pelagiella subangulata*; Elicki, p. 57, pl. 2, fig. 1.
 2003 *Pelagiella subangulata*; Elicki, Hamann, and Münzberger, p. 33, pl. 5, figs. 3, 4.
 2004 *Pelagiella subangulata*; Skovsted, p. 30, pl. 8, figs. a, b.
 2006 *Pelagiella subangulata*; Wotte, p. 151, fig. 5.n–5.p.
 2007 *Pelagiella subangulata*; Steiner et al., p. 83, fig. 7I, 7J.
 2014 *Pelagiella subangulata*; Parkhaev, p. 374, pl. 3, figs. 5, 6.
 2016 *Pelagiella subangulata*; Betts et al., p. 183, fig. 18A–18H.

Holotype.—*Ophileta subangulata* Tate, 1892 (p. 184, pl. 2, fig. 8a, 8b); “Cambrian limestone at Parara, near Ardrossan,” South Australia.

Occurrence.—About one hundred internal molds from the Grassy Spring (GS 13), Groom Range (GR 11), Log Cabin Mine (LC 6), Oak Spring Summit (OS 5), and Split Mountain (SM 14) sections; Dyeran Stage. Three internal molds from the Montezuma Range section (M 5); basal Montezuman Stage.

Description.—Small univalve internal molds up to 1 mm long and 0.4 mm high. Turbospiral and dextrally coiled with 1–1.5 rapidly expanding whorls. Last whorl wide; cross section irregular oval/trapezoidal to sub-triangular. Aperture often broken. Near convex right side of the apertural margin the residual of a projecting ear. Spire slightly submerged culminates in a plane or slightly concave left flank. Protoconch often hook-shaped. Surfaces of the molds without ornamentation.

Remarks.—Due to strong corrosion and lack of the aperture in any of the specimens, an affiliation to a definite species of *Pelagiella* Matthew, 1895 or *Costipelagiella* Horný, 1964 is difficult. *Pelagiella* is characterized by a high morphological variation, resulting in a multitude of nominated species, often with unclear differences. Even within a species, variation in

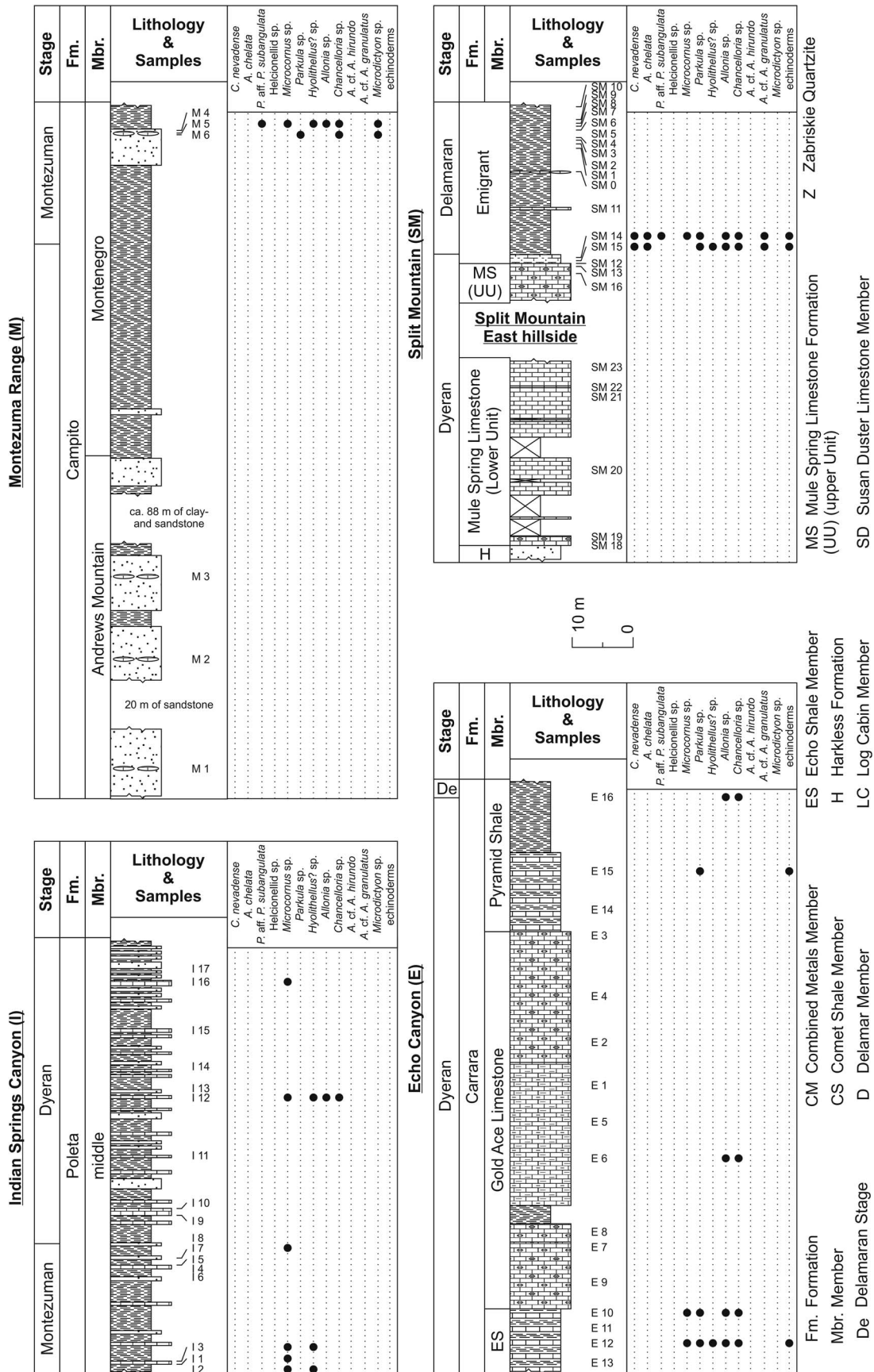


Figure 3. Stratigraphic columns of the studied outer shelf sections with positions of samples investigated. See Figure 4 for legend of lithology. The *Fallotaspis* Zone corresponds to the illustrated part of the Montezuman Stage.

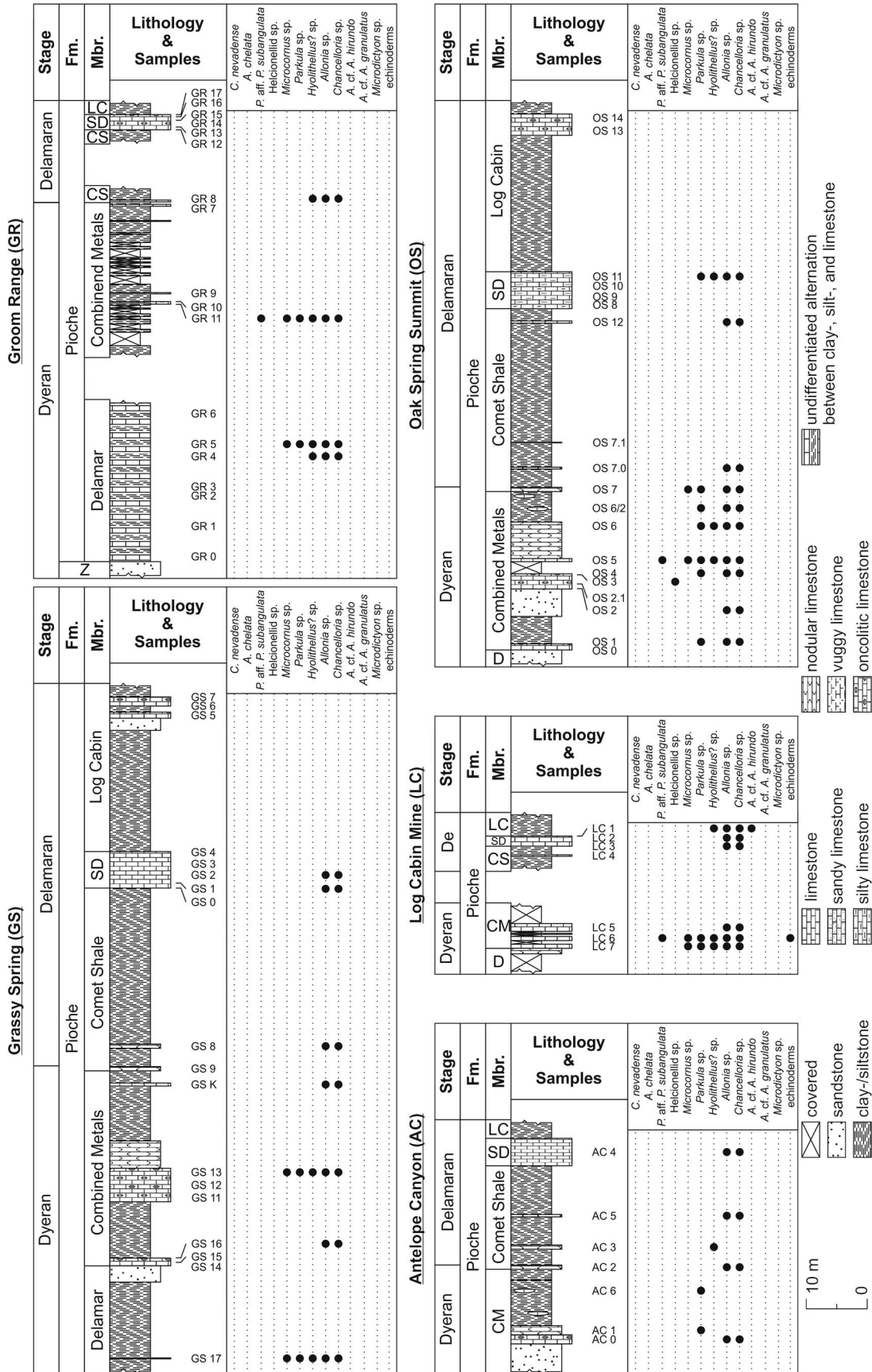


Figure 4. Stratigraphic columns of the studied middle and inner shelf sections with positions of samples investigated. For abbreviations see Figure 3.

morphology and ornamentation is large, as it is for *P. subangulata* (Tate, 1892) (Parkhaev in Gravestock et al., 2001; Skovsted, 2004). According to Parkhaev in Gravestock et al. (2001), it is most probable that *P. subangulata* and *P. medianensis* (Zhou and Xiao, 1984) represent morphologic variations of the same species. However, differences between both species are often only observable from adult forms with well-preserved shell material. According to Parkhaev in Gravestock et al. (2001), *P. medianensis* is regarded as the junior synonym of *P. adunca* (He and Pei in He et al., 1984), which thus replaces the former species name. On the other hand, it seems that *P. subangulata* continuously shifts morphologically into *P. adunca*, thus suggesting both species represent a morphological continuum within a species. Therefore, *P. medianensis* and *P. adunca* have to be revised, critically. Shell ornamentation of *P. subangulata* and *P. primaeva* (Billings, 1872 [1871]) shows comparable V-shaped ridges on the shell periphery (Runnegar in Bengtson et al., 1990; Landing and Bartowski, 1996; Landing et al., 2002). Thus, *P. primaeva* needs a careful revision as well (Skovsted, 2004).

Differences between *Pelagiella* and *Costipelagiella* are subtle and only visible on shell morphology and ornamentation. *Costipelagiella nevadense* Skovsted, 2006a originally derives from the basal Emigrant Formation of the Split Mountain section (Skovsted, 2006a), and occurs in our samples SM 14 and SM 15 as well (Fig. 5.14–5.16). Without preserved shell material, an affiliation of our internal molds to *C. nevadense* could not be excluded with certainty.

Considering the poor preservation of our material and the taxonomic discrepancies mentioned above, we interpret our specimens as having an affinity to *P. subangulata*, characterized by a wide range of variability. However, it should be kept in mind that species identification is questionable when exclusively based on internal molds (Skovsted, 2004; Topper et al., 2009).

Pelagiella subangulata is known from lower and middle Cambrian strata worldwide. Its first occurrence was recently discussed as a potential marker for defining the base of the Cambrian Series 2/Stage 3 (e.g., Steiner et al., 2007).

Helcionellid gen. and sp. indet. 1
Figure 7.7–7.12

Occurrence.—Three specimens from the middle part of the Combined Metals Member (Dyeran Stage) of Oak Spring Summit section (OS 3).

Description.—Large, weakly cyrtconic, cap-shaped shells. Apex blunt and rounded, probably located in a central position; exact position uncertain due to the complete disappearance of the aperture. Ventral cross-section of incomplete specimen OS 3/B2-3 (Fig. 7.7, 7.8) sub-circular to elliptical. Width and length ~1.3 mm and ~2.6 mm, respectively. More-complete specimens OS 3/B2-4 (Fig. 7.11, 7.12) and OS 3/B2-5 (Fig. 7.9, 7.10) with a long, slightly concave posterior field. Approximate length of these specimens is 2.2 mm and 1.2 mm, respectively. Maximum height ~1.3 mm. Anterior field gently convex. Surface with distinct radial lirae (Fig. 7.7–7.12).

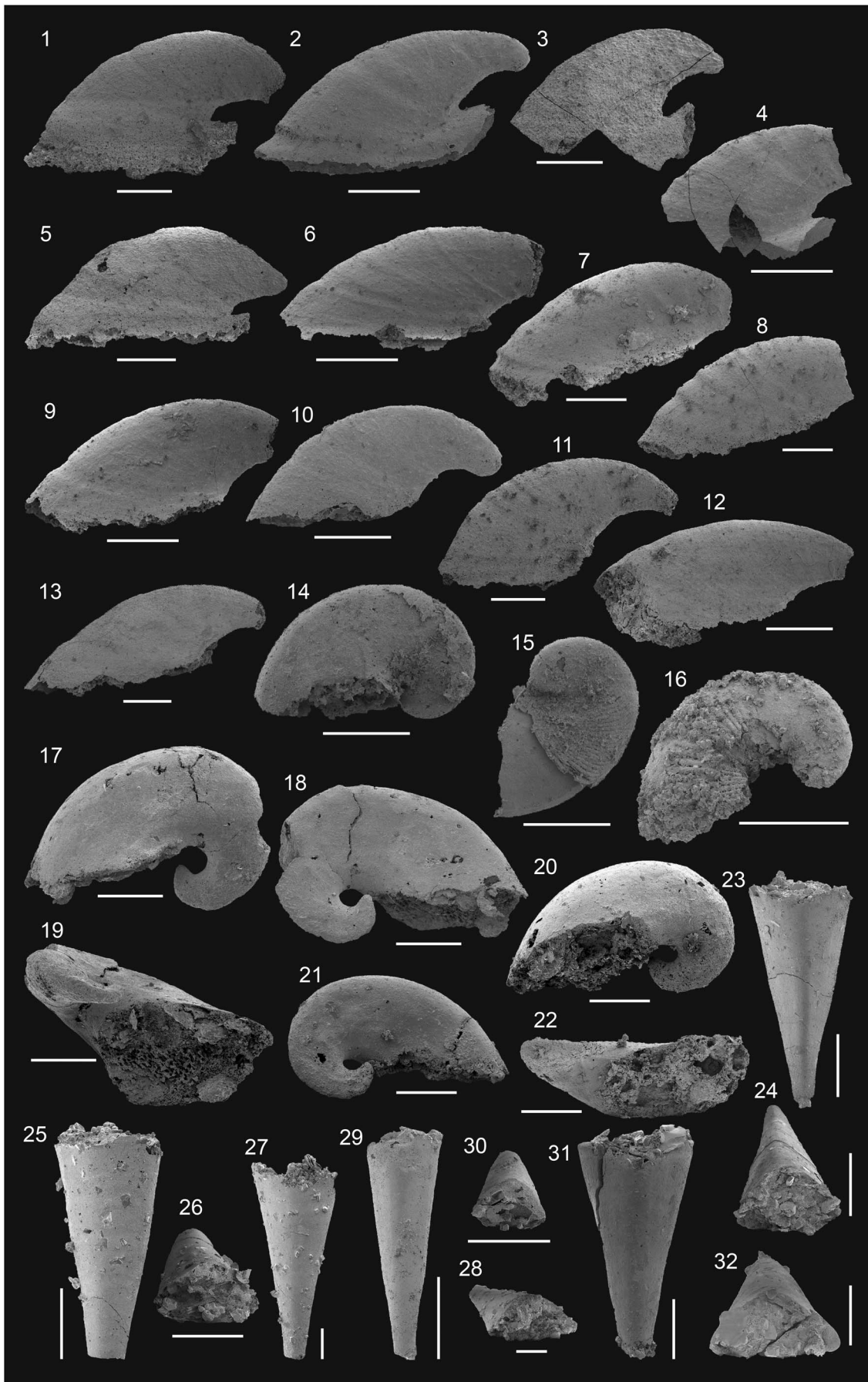
Remarks.—Specimens show similarities to several helcionelloid molluscs, such as *Trenella* Parkhaev, 2001, *Mellopegma* Runnegar and Jell, 1976, *Stenotheca* Salter in Hicks, 1872, and *Helcionella* Grabau and Shimer, 1909. The long posterior field of our specimens is similar to *Trenella* or *Mellopegma*. According to Parkhaev (2001) the posterior field of *T. bifrons* Parkhaev, 2001 is rather short and continues into a well-developed parietal train. The posterior field of the figured holotype (Parkhaev, 2001, pl. 3, fig. 1a–1c) seems to be more concave than that of our specimens. In addition, the shell of *Trenella* shows a significant lateral compression without radial lirae and the apex is more spoon-shaped. Species of *Mellopegma* are characterized by a long, slightly concave posterior field without parietal train. The elongated shell has faint comarginal rugae. The apex is blunt to slightly hooked (see Vendrasco et al., 2011). However, in comparison to our specimens, *Mellopegma* shows a significant lateral compression. There are also similarities of our material to *Stenotheca pojetai* Runnegar and Jell, 1976, showing a blunt apex and fine radial lirae. The convexity of the anterior side is similar to that of our material, but the posterior side of *S. pojetai* is more steep and short. Species of *Stenotheca* are also characterized by a strong lateral compression. A morphological similarity to *Helcionella* is given by the radial lirae and the oval cross section of the apertural region. Even if species of *Helcionella* show a wide morphological range (Jacquet and Brock, 2016), the absence of large concentric rugae and a blunter apex in our material make an affiliation to this genus questionable. Considering the sub-circular cross-section, similarities to *Miroconulus* Parkhaev in Gravestock et al. (2001) or *Anuliconus* Parkhaev in Gravestock et al. (2001) are probable. However, both taxa are characterized by concentric rugae, the apex of *Miroconulus* is slightly displaced and hooked posteriorly, and *Anuliconus* is highly conical with a posteriorly hooked apex. Therefore, it seems most probable that our Helcionellid gen. and sp. indet. 1 represents either a new species of *Helcionella* or a new genus of helcionelloid molluscs. However, the incompleteness of the material hinders a certain taxonomic affiliation.

Helcionellid gen. and sp. indet. 2
Figure 7.13–7.16

Occurrence.—Two specimens from the middle part of the Combined Metals Member (Dyeran Stage) of Oak Spring Summit section (OS 3).

Description.—Large, weakly cyrtconic, cap-shaped shells with well-developed concentric rugae (Fig. 7.13, 7.15). Apex blunt and rounded; however, specimen OS 3/B2-8 slightly hooked (Fig. 7.13). Aperture is absent, but specimens show a sub-circular to elliptical outline. Height and length of the broken specimens OS 3/B2-8 and OS 3/B2-9 are ~0.9 mm and ~1.9 mm, and ~1.5 mm and ~2.9 mm, respectively.

Remarks.—Specimens are similar to Helcionellid gen. and sp. indet. 1, but with well-developed concentric rugae and without radial lirae. Rugae, the sub-circular cross-section and the slightly hooked apex indicate an affiliation to *Helcionella*, but our material shows a blunter apex and the concentric rugae are



less prominent. Again, poor preservation prevents a secure taxonomic placement.

Phylum uncertain
Class Hyolitha Marek, 1963
Order Hyolithida Sysoiev, 1957
Family Nelegerocornidae Meshkova, 1974
Genus *Microcornus* Mambetov, 1972

Type species.—*Microcornus parvulus* Mambetov, 1972 (p. 268, fig. 1a–1e); *Rhombocorniculum cancellatum* Zone, Geres Member, basal Shabakty Formation (lower Cambrian; upper Atdabanian Stage; correlated with the lower Cambrian Stage 3); Ushbas River, Malýi (Lesser) Karatau, Kazakhstan.

Microcornus sp.
Figure 5.23–5.32

Occurrence.—Several poorly preserved internal molds of the Indian Springs Canyon and Montezuma Range sections (I 1, I 2, I 3, I 7, I 12, I 16, M 5); Montezuman Stage. Several internal molds or shells from the Echo Canyon (E 10, E 12), Grassy Spring (GS 13, GS 17), Groom Range (GR 5, GR 11), Log Cabin Mine (LC 6, LC 7), Oak Spring Summit (OS 5, OS 7), and Split Mountain (SM 14) sections; Dyeran Stage.

Description.—Slender shells or internal molds. Aperture and apex often incomplete. Incomplete specimens normally ~2 mm long (~3.3 mm maximum; Fig. 5.27). Dorsal side with distinct, rounded median ridge. Ventral side flat to gently convex. Lateral sides rounded. Cross-section sub-triangular. Protoconch absent, but probably separated from the mature conch by a shallow constriction (see Fig. 5.23). Surface sculpture not preserved.

Remarks.—*Microcornus* differs from *Parkula* Bengtson in Bengtson et al. (1990) by a more prominent dorsal median ridge and a sub-triangular cross-section. The flat to gently convex ventral side and the sub-triangular cross-section of the conch indicate affiliation to *M. eximius* Duan, 1984 or *M. petilus* Bengtson in Bengtson et al., 1990. *Microcornus eximius* is characterized by a flat ventral side, whereas *M. petilus* has a convex ventral side (Demidenko in Gravestock et al., 2001). However, the absence of opercula prevents an assignment to a species.

Family unassigned
Genus *Parkula* Bengtson in Bengtson et al., 1990

Type species.—*Parkula bounites* Bengtson in Bengtson et al., 1990 (p. 223, figs. 149–151); *Abadiella huoi* Zone, Parara

Limestone (lower Cambrian; correlated with the Cambrian Series 2); Kulpara, Yorke Peninsula, South Australia.

Parkula sp.
Figure 7.17–7.32

Occurrence.—Poorly preserved internal molds from the Montezuma Range section (M 6); Montezuman Stage. Several internal molds or shells from the Antelope Canyon (AC 1, AC 6), Echo Canyon (E 10, E 12, E 15), Grassy Spring (GS 13, GS 17), Groom Range (GR 5, GR 11), Log Cabin Mine (LC 6, LC 7), Oak Spring Summit (OS 1, OS 4, OS 5, OS 6, OS 6/2, OS 7, OS 11), and Split Mountain (SM 14, SM 15) sections; Dyeran–Delamaran stages.

Description.—Conchs with lenticular cross-section. Dorsal side with faint median ridge. Ventral side less convex than dorsal side. Aperture and apex often incomplete. Most specimens incomplete and 1 mm in length (with a maximum of 2.7 mm; Fig. 7.21). Angle of divergence 12–20°. Aperture perpendicular to the long axis of the conch. Apex slightly bulbous (Fig. 7.17, 7.19). Surface generally smooth, but a few specimens with faint transverse lines and irregularly spaced depressions of ~6 µm in diameter (Fig. 7.19, 7.25).

Remarks.—*Parkula* differs from *Microcornus* by having a faint dorsal median ridge and a lenticular to sub-triangular cross-section. Cross-section is similar to *P. esmeraldina* Skovsted, 2006a. However, poor preservation and the absence of opercula hinder a certain taxonomic affiliation.

Phylum and class uncertain
Order Hyolithelminthida Fisher, 1962
Family Hyolithellidae Walcott, 1886
Genus *Hyolithellus* Billings, 1872 (1871)

Type species.—*Hyolithes micans* Billings, 1872 (p. 215, figs. 3a, 3b); *Bonnia-Olenellus* Zone, Dyeran Stage; Troy, New York State, USA.

Hyolithellus? sp.
Figure 6.24–6.28

Occurrence.—Several fragments of internal molds from the Montezuma Range (M 5) and Indian Springs Canyon (I 2, I 3) sections; Montezuman Stage. Few fragments from the Echo Canyon section (E 12), Grassy Spring (GS 13, GS 17), Groom Range (GR 4, GR 5, GR 11), Indian Springs Canyon (I 12), Log Cabin Mine (LC 6, LC 7), Oak Spring Summit (OS 5, OS 6), and Split Mountain (SM 15) sections; Dyeran Stage. Several fragments from the Antelope Canyon (AC 3),

Figure 5. Molluscs from the Delamar and Combined Metals members of Grassy Spring and Log Cabin Mine sections and from the Emigrant Formation of Split Mountain; Dyeran Stage. (1–13) *Anabarella chelata* Skovsted, 2006a; scale bar = 200 µm; lateral views: (1) FG 544/GB/SM/14/A1-17; (2) FG 544/GB/SM/14/A1-21; (3) FG 544/GB/SM/14/A1-7; (4) FG 544/GB/SM/14/A1-1; (5) FG 544/GB/SM/14/A1-8; (6) FG 544/GB/SM/14/A1-16; (7) FG 544/GB/SM/14/A1-3; (8) FG 544/GB/SM/15/A2-4; (9) FG 544/GB/SM/14/A1-12; (10) FG 544/GB/SM/14/A1-25; (11) FG 544/GB/SM/15/A2-2; (12) FG 544/GB/SM/14/A1-22; (13) FG 544/GB/SM/15/B8-1. (14–16) *Costipelagiella nevadense* Skovsted, 2006a; scale bar = 200 µm; lateral views: (14) FG 544/GB/SM/15/B8-7; (15) FG 544/GB/SM/15/B8-10; (16) FG 544/GB/SM/14/A1-27. (17–22) *Pelagiella* aff. *P. subangulata* (Tate, 1892); scale bar = 200 µm: (17–19) FG 544/GB/LC/6/A9-11, (17, 18) lateral view, (19) oblique apertural view; (20–22) FG 544/GB/LC/6/A8-26, (20, 21) lateral view, (22) oblique apertural view. (23–32) *Microcornus* sp.; scale bar = 500 µm: (23, 24) FG 544/GB/GS/17/A4-4, (23) dorsal view, (24) oblique view from the aperture; (25, 26) FG 544/GB/GS/17/A4-12, (25) dorsal view, (26) oblique view from the aperture; (27, 28) FG 544/GB/GS/17/A4-10, (27) dorsal view, (28) oblique view from the aperture; (29, 30) FG 544/GB/GS/17/A4-6, (29) dorsal view, (30) oblique view from the aperture; (31, 32) FG 544/GB/GS/17/A5-16, (31) dorsal view, (32) oblique view from the aperture.



Groom Range (GR 8), Log Cabin Mine (LC 1), and Oak Spring Summit (OS 11) sections; Delamarian Stage.

Description.—Straight (Fig. 6.24, 6.25, 6.27, 6.28) to gently curved (Fig. 6.26) fragments with circular cross-section. Tube fragments slightly expanding. Length and width of tube fragments up to 2.4 mm and 200 μm , respectively. Internal molds smooth.

Remarks.—Classification of hyolithelminthids is primarily based on cross-section, ornamentation, and degree of tapering of the phosphatic tubes, which has resulted in a large variety of generic and specific names of often unclear differences (Landing, 1988; Bengtson et al., 1990; Skovsted, 2006b; Paterson et al., 2007; Topper et al., 2009; Skovsted and Peel, 2011; Smith et al., 2015). Following Bengtson in Gravestock et al. (2001) and Elicki (2011), we use the formal classification into hyolithellid and torellellid hyolithelminths. Internal molds described have a circular cross-section and are thus referred with some uncertainty to the hyolithellid genus *Hyolithellus* Billings, 1872 (1871).

Phylum uncertain

Class Coeloscleritomorpha Bengtson and Missarzhevsky, 1981

Order Chancelloriida Walcott, 1920

Family Chancelloriidae Walcott, 1920

Remarks.—Several samples have produced isolated rays that cannot be assigned to a particular genus within this family. These are listed as chancelloriid spicules even though they may belong to co-occurring taxa listed below.

Genus *Allonnia* Doré and Reid, 1965

Type species.—*Allonnia tripodophora* Doré and Reid, 1965 (p. 20, fig. 1); Carteret Formation (lower Cambrian; correlated with the Cambrian Series 2); Carteret, Cotentin Peninsula, Normandy, France.

Allonnia sp.
Figure 8.9–8.11

Occurrence.—Several spicules from the Antelope Canyon (AC 0, AC 2, AC 4, AC 5), Echo Canyon (E 6, E 10, E 12, E 16), Grassy Spring (GS 1, GS 2, GS 8, GS 13, GS 16, GS 17, GS K), Groom Range (GR 4, GR 5, GR 8, GR 11), Indian Springs Canyon (I 12), Log Cabin Mine (LC 1, LC 2, LC 3, LC 5, LC 6, LC 7), Montezuma Range (M 5), Oak Spring Summit (OS 1, OS 2, OS 4, OS 5, OS 6, OS 6/2, OS 7, OS 7.0, OS 11, OS 12), and Split Mountain (SM 14, SM 15) sections; Montezuman–Delamarian stages.

Description.—Poorly preserved spicules with 4+0 rays slightly diverge from the basal plane.

Remarks.—Chancelloriids with 2+0, 3+0, and 4+0 rays are referred to the genus *Allonnia* (see Qian and Bengtson, 1989; Moore et al., 2013). Orientation and arrangement of our four-rayed spicules indicate a systematic affiliation to *A. tetrathallis* (Jiang in Luo et al., 1982).

Genus *Chancelloria* Walcott, 1920

Type species.—*Chancelloria eros* Walcott, 1920 (p. 329–331, pl. 86, figs. 2, 2a–c; pl. 88, figs. 1, 1a–f); *Ogygopsis* Zone, Burgess Shale Member, Stephen Formation (middle Cambrian; correlated with the Cambrian Series 3); northeast of Burgess Pass, British Columbia, Canada.

Chancelloria sp. 1
Figure 8.12–8.15

Occurrence.—Hundreds of spicules from the Log Cabin Mine (LC 6) and Oak Spring Summit (OS 4) sections; Dyeran Stage.

Description.—Poorly preserved spicules with 6+0 rays. Rays slightly bent upwards from the basal plane. Foramen on the lower side rounded to oval (Fig. 8.14).

Remarks.—Detailed systematic affiliation is difficult due to poor preservation. Shape and organization of spicules suggest an affiliation to *Chancelloria*. However, an affiliation to *Archiasterella* Sdzuy, 1969 (e.g., *A. elegans* Demidenko in Gravestock et al., 2001) could not be excluded.

Chancelloria sp. 2
Figure 8.16–8.22

Occurrence.—Thousands of spicules and large number of isolated rays from the Antelope Canyon (AC 0, AC 2, AC 4, AC 5), Echo Canyon (E 6, E 10, E 12, E 16), Grassy Spring (GS 1, GS 2, GS 8, GS 13, GS 16, GS 17, GS K), Groom Range (GR 4, GR 5, GR 8, GR 11), Indian Springs Canyon (I 12), Log Cabin Mine (LC 1, LC 2, LC 3, LC 5, LC 6, LC 7), Montezuma Range (M 5), Oak Spring Summit (OS 1, OS 2, OS 4, OS 5, OS 6, OS 6/2, OS 7, OS 7.0, OS 11, OS 12), and Split Mountain sections (SM 14, SM 15); Montezuman–Delamarian stages.

Description.—Spicules with 5+1 broken rays. The vertical ray is more robust and shorter than the lateral rays. Rays slightly bent upwards from the basal plane.

Figure 6. Small shelly fossils from the Campito, Delamar, Echo Shale, Combined Metals members of Montezuma Range, Echo Canyon, Grassy Spring, Oak Spring Summit, Log Cabin Mine sections as well as from the basal Emigrant Formation of Split Mountain; Montezuman–Dyeran stages; all scale bars 200 μm : (1–23) *Pelagiella* aff. *P. subangulata* (Tate, 1892): (1–3) FG 544/GB/LC/6/A9-12, (1, 2) lateral view, (3) oblique apertural view; (4–6) FG 544/GB/LC/6/A9-19, (4, 5) lateral view, (6) oblique apertural view; (7–9) FG 544/GB/LC/6/A9-33, (7, 8) lateral view, (9) oblique apertural view; (10–12) FG 544/GB/SM/14/A1-13, (10, 11) lateral view, colonization of endolithic cyanobacteria on the internal mold, (12) oblique apertural view; (13, 14) FG 544/GB/OS/5/A12-13, lateral view; (15) FG 544/GB/GR/11/A10-11, lateral view; (16) FG 544/GB/GR/11/A10-22, lateral view; (17–19) FG 544/GB/GR/11/A10-6, (17, 18) lateral view, (19) oblique apertural view; (20–22) FG 544/GB/GR/11/A10-31, (20, 21) lateral view, (22) oblique apertural view; (23) FG 544/GB/GS/13/A6-14, oblique lateral view. (24–28) *Hyolithellus*? sp.: (24) FG 544/GB/M/5/C8-2; (25) FG 544/GB/LC/6/A8-1; (26) FG 544/GB/M/5/C8-1; (27) FG 544/GB/M/5/C8-3; (28) FG 544/GB/GS/17/A5-11.

Remarks.—Spicules show a flat base and an almost radial symmetry. Number and arrangement of the rays indicates a systematic affiliation to *Chancelloria*.

Genus *Archiasterella* Sdzuy, 1969

Type species.—*Archiasterella pentactina* Sdzuy, 1969 (p. 134–137, pl. 15, fig. 4–12, 13?, text figs. 2d, 3, 4); *Andalusiana cornuta-Termierella sevillana* band (lower Cambrian; middle Marianian Stage; correlated with the uppermost Terreneuvian/Cambrian Stage 2); basin of Guadalcanal, Sierra Morena, southern Spain.

Archiasterella cf. *A. hirundo* Bengtson in Bengtson et al., 1990
Figure 8.23

Occurrence.—One spicule from the Log Cabin Mine section (LC 1); Delamaran Stage.

Description.—Spicule with 4+0 rays. Specimen strongly recrystallized.

Remarks.—Configuration and arrangement of rays suggests a similarity with *A. hirundo* Bengtson in Bengtson et al., 1990.

Phylum Echinodermata Klein, 1734
Indeterminate echinoderm ossicles
Figure 8.1–8.8

Occurrence.—Several ossicles from the Echo Canyon (E 12, E 15), Log Cabin Mine (LC 6), and Split Mountain (SM 14, SM 15) sections; Dyeran Stage.

Remarks.—Echinoderm ossicles with preserved stereome microstructure. Morphology ranges from plates, irregular segments, to barrel-shaped segments, typical for eocrinoids and edriasteroids. However, no assignment to a particular taxon is possible.

Phylum Tardipolypoda Chen and Zhou, 1997
Class Xenusia Dzik and Krumbiegel, 1989
Order Scleronychophora Hou and Bergström, 1995
Family Eoconchariidae Hao and Shu, 1987

Genus *Microdictyon* Bengtson, Matthews, and Missarzhevsky
in Missarzhevsky and Mambetov, 1981

Type species.—*Microdictyon effusum* Bengtson, Matthews, and Missarzhevsky in Missarzhevsky and Mambetov, 1981 (p. 78, pl. 13, figs. 3, 5); *Rhombocorniculum cancellatum* Zone, Geres Member, basal Shabakty Formation (lower Cambrian; upper

Atdabanian Stage; correlated with the lower Cambrian Series 2); Ushbas River, Malyi (Lesser) Karatau, Kazakhstan (see Mambetov and Missarzhevsky, 1972).

Microdictyon montezumaensis new species
Figure 8.24–8.25

Holotype.—Specimen FG 544/GB/M/5/C8-8 from sample M 5 from the upper *Fallotaspis* Zone of the Montenegro Member; middle Montezuman Stage; 5 m below the 127 m aluminum tag; Montezuma Range section.

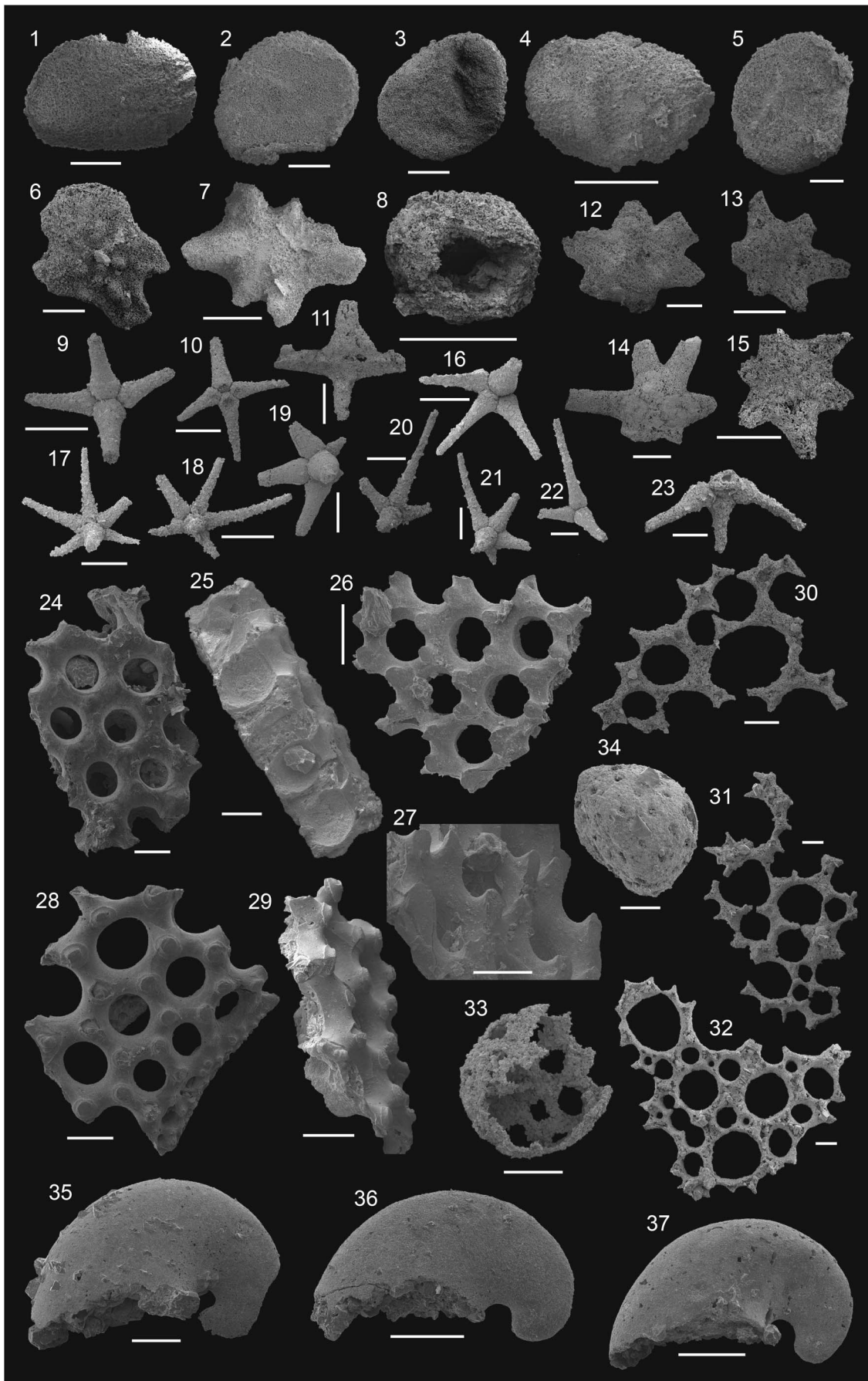
Diagnosis.—*Microdictyon* with simple, smooth nodes.

Description.—One fragment of ~180 µm thickness (Fig. 8.25). Sclerite composed of a dense crystalline layer (capping, sensu Bengtson et al., 1986) forming its surface and the walls/bases of holes, and a coarser crystalline layer hosting the holes (framework, sensu Bengtson et al., 1986). Holes surrounded by a prominent ridge (Fig. 8.24, 8.25). Cross-section of holes clearly shows the relationship between holes and ridges, offering a barrel-shaped structure (Fig. 8.25). At the capping, hole diameters constricting from ~80 µm to ~50 µm, extending into bulbous cavities (width of 120 µm in their central part) in the framework. Holes surrounded by six regularly arranged weak nodes (Fig. 8.24, 8.25).

Etymology.—Named after Montezuma Range.

Remarks.—The exact determination of *Microdictyon* species is primarily based on the morphology of the nodes surrounding the holes. A further aspect is the hole diameter and a common basal closure of the holes. The last feature is a typical characteristic of *M. effusum* (Bengtson et al., 1986, p. 101, fig. 3). However, the absence of such a basal closure in all other described species of *Microdictyon* may be an artifact of preservation. According to the original description, the nodes of *M. effusum* have a mushroom-like shape, although this and the basal closure are not observable on the figured material (Bengtson et al. in Missarzhevsky and Mambetov, 1981, pl. 13, figs. 3, 5). Bengtson et al. (1986) described a distinct brim and a sub-centrally placed apex for *M. effusum*. Nodes of our sclerite show no prominent relief (Fig. 8.24, 8.25). However, the good preservation of the surface layer indicates no or only minor erosion, thus excluding a destruction of prominent nodes. Therefore, the gentle morphology on the sclerite is considered as representing the original shape. Because the structure of the nodes is an essential criterion for species definition, it is necessary to assign this fragment to the new species *M. montezumaensis*.

Figure 7. Small shelly fossils from the Delamar, Echo Shale, and Combined Metals members of Echo Canyon, Grassy Spring, Groom Range, and Oak Spring Summit sections; Dyeran Stage. (1–6) *Pelagiella* aff. *P. subangulata* (Tate, 1892); scale bar = 200 µm: (1–3) FG 544/GB/GS/13/A6-8, (1, 2) lateral view, (3) oblique apertural view; (4–6) FG 544/GB/GR/11/A10-14, (4, 5) lateral view, (6) oblique apertural view. (7–12) Helcionellid gen. and sp. indet. 1; note the fine radial lirae in the apical region: (7, 8) FG 544/GB/OS/3/B2-3; scale bar = 500 µm; (7) lateral view, (8) apical view; (9, 10) FG 544/GB/OS/3/B2-5; scale bar = 200 µm; (9) lateral view, (10) apical view; (11, 12) FG 544/GB/OS/3/B2-4; scale bar = 500 µm; (11) lateral view, (12) apical view. (13–16) Helcionellid gen. and sp. indet. 2; scale bar = 500 µm; note the well-developed concentric rugae in the apical region: (13, 14) FG 544/GB/OS/3/B2-8, (13) lateral view, (14) apical view; (15, 16) FG 544/GB/OS/3/B2-9, (15) lateral view, (16) apical view. (17–32) *Parkula* sp.; scale bars 400 µm except for (25, 26, 31, 32) (200 µm): (17, 18) FG 544/GB/GS/13/A6-2, (17) dorsal view, (18) oblique view from the aperture; (19, 20) FG 544/GB/E/12/B6-17, (19) dorsal view, (20) oblique view from the aperture; (21, 22) FG 544/GB/GS/17/A4-14, (21) dorsal view, (22) oblique view from the aperture; (23, 24) FG 544/GB/GS/17/A5-15, (23) dorsal view, (24) oblique view from the aperture; (25, 26) FG 544/GB/E/12/B6-7, (25) dorsal view, (26) oblique view from the aperture; (27, 28) FG 544/GB/GS/17/A5-16, (27) dorsal view, (28) oblique view from the aperture; (29, 30) FG 544/GB/E/10/A3-5, (29) dorsal view, (30) oblique view from the aperture; (31, 32) FG 544/GB/E/10/A3-2, (31) dorsal view, (32) oblique view from the aperture.



It should be kept in mind that individual complete plates of *Microdictyon* could combine features (e.g., node morphology) diagnostic for a range of species (Chen et al., 1989; Topper et al., 2011). The simple, hump-like nodes of *Microdictyon montezumaensis* n. sp. are singular for this species and not known from other fragments and complete plates of *Microdictyon*. However, it couldn't be excluded that the generally applied diagnostic characteristics result in a multitude of different species of *Microdictyon*, probably overestimating the real taxonomic diversity, and thus have to be critically revised.

Most *Microdictyon* sclerites are found in lower Cambrian successions worldwide. Few specimens are known from the middle Cambrian (*Ptychagnostus gibbus* Zone) of Utah and Bornholm, both probably representing reworked lower Cambrian material (Bengtson et al., 1986; Berg-Madsen, 1981).

Microdictyon cuneum new species
Figure 8.26, 8.27

Holotype.—Fragmented specimen FG 544/GB/M/5/C8-17 from sample M 5 from the upper *Fallotaspis* Zone of the Montenegro Member; middle Montezuman Stage; 5 m below the 127 m aluminum tag; Montezuma Range section.

Diagnosis.—*Microdictyon* with short, wedge-shaped nodes.

Description.—Fragment with fully preserved, dense crystalline capping and partly preserved, coarse crystalline framework. Thickness ~50 µm. Hole diameter nearly uniform, ~75 µm. Nodes wedge shaped, gradually develop from ridges that surround the holes. One side of the nodes forms an angle of ~30° with the ridge surface forming the wedge shape. Other side of nodes forms an overhang or an acute angle to the ridge. Wedge-shaped nodes are oriented into the same direction.

Etymology.—Latin *cuneus*, meaning wedge. Referring to the wedge-shaped appearance of the nodes.

Remarks.—Only two species of *Microdictyon* are characterized by spike-shaped nodes: *Microdictyon robisoni* Bengtson, Matthews, and Missarzhevsky, 1986 shows tall and narrow nodes ending in slight expansions. These expansions are clearly offset from the basal socket, which is not present in our specimen. Nodes of *M. sphaeroides* Hinz, 1987 develop from a smaller base to a wide, flat rim, finally culminating in a sloped spine. Therefore, node morphology of both species is completely different compared to *M. cuneum* n. sp. Nodes of

M. cuneum n. sp. develop continuously from the rim of the capping showing no offset or rim. They are also shorter than the spiny nodes of *M. robisoni*.

Microdictyon rhomboidale Bengtson, Matthews, and
Missarzhevsky, 1986
Figure 8.28, 8.29

- 1986 *Microdictyon rhomboidale* Bengtson, Matthews, and Missarzhevsky, p. 102, figs. 4–6.
1987 *Microdictyon* sp.; Voronova et al., p. 56, pl. 24, figs. 6–7.
1992 *Microdictyon rhomboidale*; Bengtson and Conway Morris, p. 461, fig. 2F.
2007 *Microdictyon* aff. *rhomboidale*; Zhang and Aldridge, p. 405, fig. 2N–2R.
2013 *Microdictyon rhomboidale*; Bengtson and Conway Morris, p. 461, fig. 2F.
2015 *Microdictyon* cf. *rhomboidale*; Kouchinsky et al., p. 481, fig. 55.
2015 *Microdictyon* sp.; Kouchinsky et al., p. 481, fig. 56.

Holotype.—*Microdictyon rhomboidale* Bengtson et al., 1986 (figs. 4–6); lower Cambrian (upper Atdabanian or lower Botoman stages; correlated with the middle to upper Cambrian Stage 3); north of Bograd village, Batney Hills, Kuznetskij Alatau Range, Republic of Khakassia, Russia (see Zadorozhnaya et al., 1973).

Occurrence.—One fragment from sample M 5 from the upper *Fallotaspis* Zone of the Montenegro Member; middle Montezuman Stage; 5 m below the 127 m aluminum tag; Montezuma Range section.

Description.—Holes are circular to sub-circular, decreasing in size towards the rim, range of 115 µm to 14 µm near margin. Nodes slightly mushroom-shaped with distinct brim.

Remarks.—The capping of the fragment is completely preserved, whereas the major part of the framework is corroded. The fragment represents the periphery of a complete sclerite with a steep rim (Fig. 8.28). The shape of the nodes is typical for *M. rhomboidale* Bengtson et al., 1986. The fragment compares well to *Microdictyon* n. sp. 1 of Bengtson et al. (1986) described from the region 42 km south of Goldfield (Esmeralda County, Nevada; Albers and Stewart, 1972). The material is derived from the lower *Nevadella* Zone and is thus stratigraphically slightly younger than the fragments described herein. According

←
Figure 8. Small shelly fossils from the Echo Shale, Pyramid Shale, Combined Metals, and Comet Shale members of the Montezuma Range, Oak Spring Summit, and Log Cabin Mine sections, as well as from the basal Emigrant Formation of Split Mountain; Montezuman–Delamaran stages. (1–8) indeterminate echinoderm ossicles; scale bar = 400 µm: (1) FG 544/GB/E/12/B1-2; (2) FG 544/GB/E/15/B4-9; (3) FG 544/GB/E/15/B4-5; (4) FG 544/GB/E/12/B1-1; (5) FG 544/GB/E/15/B4-10; (6) FG 544/GB/E/16/B4-2; (7) FG 544/GB/SM/15/B8-5; (8) FG 544/GB/E/12/B1-6. (9–11) *Allomia* sp.; scale bar = 400 µm: (9) FG 544/GB/OS/7/C11-13; (10) FG 544/GB/OS/7/C11-22; (11) FG 544/GB/OS/4/C2-13. (12–15) *Chancelloria* sp. 1; scale bar = 400 µm except (14) (700 µm): (12) FG 544/GB/LC/6/A8-3; (13) FG 544/GB/LC/6/A8-4; (14) FG 544/GB/OS/4/C2-12; (15) FG 544/GB/LC/6/A8-5. (16–22) *Chancelloria* sp. 2; scale bar = 300 µm: (16) FG 544/GB/OS/7/C11-11; (17) FG 544/GB/OS/7/C11-12; (18) FG 544/GB/OS/7/C11-10; (19) FG 544/GB/OS/7/C11-21; (20) FG 544/GB/OS/7/C11-18; (21) FG 544/GB/OS/7/C11-15; (22) FG 544/GB/OS/7/C11-4. (23) *Archasterella* cf. *A. hirundo* Bengtson in Bengtson et al., 1990; FG 544/GB/LC/11/B3-7; scale bar 300 µm. (24, 25) Holotype of *Microdictyon montezumaensis* n. sp.; FG 544/GB/M/5/C8-8; scale bar = 100 µm: (24) ventral view, (25) lateral view of (24). (26, 27) Holotype of *Microdictyon cuneum* n. sp.; FG 544/GB/M/5/C8-17: (26) ventral view; scale bar 100 µm, (27) detail of (26); scale bar 50 µm. (28, 29) *Microdictyon rhomboidale* Bengtson et al., 1986; scale bar = 100 µm: (28) FG 544/GB/M/5/C8-9, (29) oblique lateral view of (28). (30–32) *Microdictyon* sp.; scale bar = 100 µm: (30) ventral view; FG 544/GB/M/5/C6-8; (31) ventral view; FG 544/GB/M/6/B10-3; (32) ventral view; FG 544/GB/M/6/B10-2. (33, 34) *Archaeooides* cf. *A. granulatus* Qian, 1977; scale bar = 100 µm: (33) FG 544/GB/SM/15/B8-20; (34) FG 544/GB/SM/14/A1-5. (35–37) *Pelagiella* aff. *P. subangulata* (Tate, 1892); scale bar = 200 µm: (35) FG 544/GB/M/5/C8-13, lateral view; (36) FG 544/GB/M/5/C8-12, lateral view; (37) FG 544/GB/M/5/C8-11, lateral view.

to Bengtson et al. (1986) their Nevadan material could be most probably referred to *M. cf. rhomboidale*. Due to the stratigraphic and regional closeness of both settings, an affiliation of our fragment to *M. rhomboidale* is most probable.

Microdictyon sp.
Figure 8.30–8.32

Occurrence.—Several fragments from samples M 5 and M 6 from the upper *Fallotaspis* Zone of the Montenegro Member; middle Montezuman Stage; M 5 and M6 are located 5 m and 6 m, respectively, below the 127 m aluminum tag; Montezuma Range section.

Description.—Thin phosphatic plate fragments with hexagonal meshwork. The plates represent only the upper capping. Hole diameter ranges from 85 μm and 180 μm on the slightly convex surface and decreases to <9 μm towards the periphery. Fragments strongly corroded, obliterating any prominent surface and probably enlarging hole diameters.

Remarks.—Due to the insufficient preservation of our fragments no exact determination is possible.

Genus *Archaeooides* Qian, 1977

Type species.—*Archaeooides granulatus* Qian, 1977 (pl. 2, fig. 21); Meishucunian Stage (correlated with the Cambrian Stage 2); central and southwest China.

Archaeooides cf. A. granulatus Qian, 1977
Figure 8.33, 8.34

Occurrence.—Two specimens from samples SM 14 and SM 15 from the lowermost Emigrant Formation of the Split Mountain section; Samples SM 14 and SM 15 are derived 1.0 m respectively 0.5 m above the base of the Emigrant Formation; Dyeran Stage.

Description.—Well-rounded to flattened on one side, hollow, ranging from 250 μm (Fig. 8.33) to 365 μm (Fig. 8.34) in diameter. Surface with crystalline texture and covered with circular to oval pits 15–23 μm in diameter.

Remarks.—The spherical specimen from sample SM 15 (Fig. 8.33) is similar to the ‘perforated sphere’ published by Skovsted (2006a, fig. 4C) from the same locality but from a slightly higher stratigraphic position (~1.4 m above the base of the Emigrant Formation). The absence of a flattened area suggesting an encrusting lifestyle of the organism excludes an affiliation of both spheres to *Aetholicopalla* Conway-Morris in Bengtson et al., 1990. There is also no indication for a double-walled surface, even if an erosion of the outer wall could not be excluded. The spheres show clear similarities to *Archaeooides granulatus* Qian, 1977, which are single-walled. The surface of *A. granulatus* and related synonyms (e.g., *A. kuanchuanpuensis* Qian, 1977, *A. acuspinitus* Qian, 1977, *Gaparella porosa* Missarzhevsky in Missarzhevsky and Mambetov, 1981) is characterized by porous tubercles with pore diameters ranging

from 10 μm to 30 μm (Missarzhevsky and Mambetov, 1981; Missarzhevsky, 1989; Parkhaev and Demidenko, 2010). Surface ornamentations of the specimen of sample SM 15 and that figured by Skovsted (2006a) are probably corroded.

The specimen of sample SM 14 (Fig. 8.34) shows a slightly convex area, which could be interpreted as a zone of attachment of the organism on the substrate, typical for *Aetholicopalla granulata* Conway Morris in Bengtson et al., 1990. However, the occurrence of pores, even on this area, points against an encrusting life mode of the hemisphere. There is further no indication for a double-wall that necessary for defining this subsphere to *Aetholicopalla*. The porous structure of the surface indicates an association to *Archaeooides granulatus*, even if a prominent sculpture/ornamentation does not occur. *Archaeooides granulatus* is characterized by a wide morphology, ranging from spheres, ellipsoids, and hemispheres to spheres flattened on two opposite sides (see Parkhaev and Demidenko, 2010). The specimen of sample SM 15 fits into this morphological range. The pores of the Laurentian specimens are fewer than known from *Archaeooides*. However, based on their (hemi)spheroidal morphology and the single wall, the Laurentian organisms from samples SM 14 and SM 15 and the specimen of Skovsted (2006a) are referred to *Archaeooides cf. A. granulatus* Qian, 1977.

The general stratigraphic occurrence of *Archaeooides* and *Aetholicopalla* is the Tommotian–Botoman interval of the Siberian nomenclature, which is the Meishucunian–Nangaoan stages of the Chinese nomenclature. The record of the Laurentian *Archaeooides* slightly below the Dyeran–Delamarian boundary most probably represents the youngest occurrence of these organisms worldwide.

Discussion

Fossil distribution patterns are most probably an artifact of the chemical preparation that eliminated portions of the calcareous microfossils. Helcionelloid molluscs, hyoliths, and hyolithelminths occur in almost all sections investigated for the inner, middle, and outer shelf environments of Nevada and California. Sclerites of sponges and chancelloriids are almost absent at Grassy Spring section (inner shelf), whereas echinoderm ossicles only occur at Split Mountain (outer shelf), Echo Canyon, and Log Cabin Mine sections (both inner shelf; Figs. 3, 4).

Occurrences of *Pelagiella* aff. *P. subangulata* and several species of *Microdictyon* in the lower part of the Montezuman Stage in the Montezuman Range section are most probably important for biostratigraphic correlation. Taxa such as *Pelagiella subangulata*, *Microdictyon effusum*, and the tooth-like sclerite *Rhombocorniculum cancellatum* (Cobbold, 1921) are characterized by an almost worldwide distribution and are thus useful for correlation of Cambrian Series 2/Stage 3 (Li et al., 2003; Steiner et al., 2007; Rozanov et al., 2008). Well-established biozonations based on SSF assemblages including these taxa were used in Siberia (the so-called Tommotian fauna; e.g., Khomentovsky and Karlova, 1993), Australia (e.g., Gravestock et al., 2001; Jago et al., 2002, 2006), and South China (e.g., Qian, 1999). Steiner et al. (2007) using the *P. subangulata* and the *R. cancellatum* taxon-range zones for the base of Cambrian Series 2 have provided detailed correlation between several regions of the

Yangtze Platform. Both zones contain additional important faunal elements (e.g., *M. effusum*, hyoliths, bradoriids, and brachiopods). According to Steiner et al. (2007), the *P. subangulata* range Zone of the Qiongzhusian of South China appears to correlate with the *P. lorenzi* Zone of the middle–late Atdabanian of the Siberian Platform. Furthermore, the occurrence of *P. subangulata*, *R. cancellatum*, and *M. effusum* indicates a correlation with the *Camenella baltica* Zone of Avalonia and Newfoundland (Landing et al., 1980; Hinz, 1987; Landing, 1988). The occurrence of *Pelagiella* aff. *P. subangulata* and species of *Microdictyon* from the lower Montezuman Stage of the Montezuma Range section most probably corresponds with the bases of the taxon-range zones of South China, Siberia, and Avalonia. It therefore most probably identifies the base of Cambrian Series 2/Stage 3 in Nevada and enables the correlation of western Laurentia with these regions. However, the verification of SSF associations suitable for a global correlation of the basal Cambrian Series 2 needs further critical and comprehensive evaluation, as indicated by Landing et al. (2013).

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