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HOLMIIDAE (TRILOBITA: OLENELLINA) OF THE MONTEZUMAN STAGE (EARLY CAMBRIAN) IN WESTERN NEVADA

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ABSTRACT—Holmiids are a major component of the trilobite fauna in the middle part of the Montezuman Stage, the lowermost stage of the Cambrian of Laurentia with a continuous trilobite record. They are less common in the upper Montezuman where nevadiids predominate and other trilobite families appear. New material from western Nevada allows a revision of these holmiids. *Palmettaspis parallela* Fritz, 1995 and *Palmettaspis cometes* (Fritz, 1995) are assigned to a new genus, *Montezumaspis*, based primarily on thoracic characters, including a prominent axial spine on the thorax. A second new genus, *Grandinasus*, is based on *Esmeraldina argenta* (Walcott, 1910), in which the L3 lobe is incorporated in an expanded anterior lobe (LA) of the glabella. New species described are *Esmeraldina elliptica*, *Grandinasus auricampus*, *G. patulus*, *Holmiella falx*, and *H. millerensis*. The Laurentian taxa appear to be more primitive than the holmiids of Baltica by having simple, unfurrowed ocular lobes that are separated from the LA by an axial furrow. Three informal biofacies are suggested with a holmiid-dominated biofacies in a deep subtidal dysoxic environment, and two nevadiid-dominated biofacies in shallower subtidal environments.

INTRODUCTION

INTERCONTINENTAL CORRELATION of the lower part of the Cambrian is complicated by the provinciality of the trilobite faunas (Palmer, 1998b, 1998c) and the long ranges of small shelly fossils (Qian and Bengtson, 1989). Until recently, the lack of a formal stage nomenclature for the lower Cambrian of Laurentia has been an additional problem for such Cambrian correlations (Palmer, 1995). In 1992, W. H. Fritz began a field program to study the biostratigraphy surrounding the base of the Waucoban Series in Nevada (Walcott, 1912a; Fritz, 1995); I joined Fritz in this effort. Palmer (1998c) formally proposed a stage nomenclature for Laurentia, including the Montezuman and Dyeran stages (Fig. 1) based on some of this field work. The base of the Montezuman Stage is drawn on the base of the abundance zone of an *Eofallotaspis*-like trilobite found in the western part of the Montezuma Range, Esmeralda County, Nevada (Fig. 2.5), boundary stratotype section MW-3S (Hollingsworth, 1999a). This point is approximately 30 m above the base of the Montenegro Member of the Campito Formation. The stage includes the "*Fallotaspis*" and "*Nevadella*" zones of Fritz (1972; Palmer and Repina, 1993). The base of the succeeding Dyeran Stage is at the base of the *Olenellus* Zone (Fritz, 1972; Palmer and Repina, 1993) in the middle member of the Poleta Formation (Fig. 1), boundary stratotype section IS-4, in Indian Springs Canyon, northern Montezuma Range (Figs. 2.5, 3) (Hollingsworth, 1999b).

Studies of the trilobite faunas of the Montezuman Stage in the Great Basin began when Walcott (1910) described several forms collected from the lower Cambrian of Esmeralda County and adjacent areas of California. Nelson (1976; also Nelson and Durham, 1966) illustrated a few of the many trilobites found during field mapping in California. Otherwise, the faunas of this area languished until Fritz (1995) redescribed the fauna of Walcott's 1f collection from Barrel Spring in Esmeralda County (Fig. 2, for details see *Discussion of Palmettaspis consorta* Fritz, 1995). More recently, Lieberman (2001, 2002) and McMenamin (2001) described a few trilobites from the Montezuman Stage. This report deals only with the holmiids of the Montezuman Stage in western Nevada. The Holmiidae are the first elements of the Olenelloidea, a predominant lower Cambrian trilobite group (Palmer and Repina, 1997). Here they are preceded by fallotaspidids and archaeaspidids. The holmiids appear at essentially the same point as the nevadiids.

STRATIGRAPHY

The materials used in this study come primarily from six measured sections through parts of the Montenegro Member of the Campito Formation and the Poleta Formation in the northern Montezuma Range (Figs. 2.5, 3, 4) and from several other measured sections and sites in various other mountain ranges of Esmeralda County, Nevada (Fig. 2). A composite of the individual sections in the Montezuma Range (Fig. 5) shows the occurrence and ranges of all holmiid material discussed herein.

Lithostratigraphy.—In the Montezuma Range, the Montenegro Member of the Campito Formation (Fig. 5) is 349 m thick. The lower 144 m is light brown sericitic siltstone and fine sandstone. The next 21 m interval contains siltstone with quartzite and sandstone beds, and lenses of bioclastic carbonate packstone and glauconitic arenaceous limestone. Trace fossils, ripple marks, and soft-sediment deformation features are common. This interval is interpreted as a transgressive event. The upper 184 m of the Montenegro Member is greenish gray shaly siltstone with occasional lenses of fine sandstone. Near the top of the member there are thin beds of sandstone and bioclastic limestone. Beginning 36 m above the base of the member and extending to the top, trilobites are rare to common with fewer brachiopods and hyoliths. In other mountain ranges of Esmeralda County, cleavage and metamorphism frequently preclude recovery of fossils from the Montenegro Member.

The overlying Poleta Formation is divided into three informal members (McKee and Moiola, 1962; Stewart, 1970), a lower carbonate member, a middle siliciclastic-carbonate member, and an upper carbonate member. In the Montezuma Range, the lower member can be further subdivided into three units. The lower unit begins with 2 m of very light brown clayey shale with lesser thin beds of micritic carbonate in sharp contact with Montenegro siltstone, then grades rapidly upward into thin-bedded limestone with minor interbeds of shale and dolomite for 31 m. Archaeocyathids occur in some of the upper beds, and trilobites are rare, except in bioclastic beds near the top of this unit. The second unit is 29 m of light brown shale with locally common trilobite sclerites and brachiopods. This is succeeded by the main carbonate unit of the lower Poleta, about 70–80 m thick, incorporating beds and bioherms of algal-archaeocyathan boundstones and medium to thick beds of carbonate grainstone, often oolitic. Elsewhere in Esmeralda County, the lower Poleta varies considerably from this simple picture. To the west, at the Fish Lake Valley section (Fig. 2.2), the intermediate shale unit of the lower Poleta is much thicker and contains isolated mounds of algal-archaeocyathan limestone. Southward, at the Stewart Mill (Fig. 2.7) section, the lower thin-bedded carbonate grades rapidly upward to thrombolitic then algal-archaeocyathan carbonate, and the intermediate shale is thin
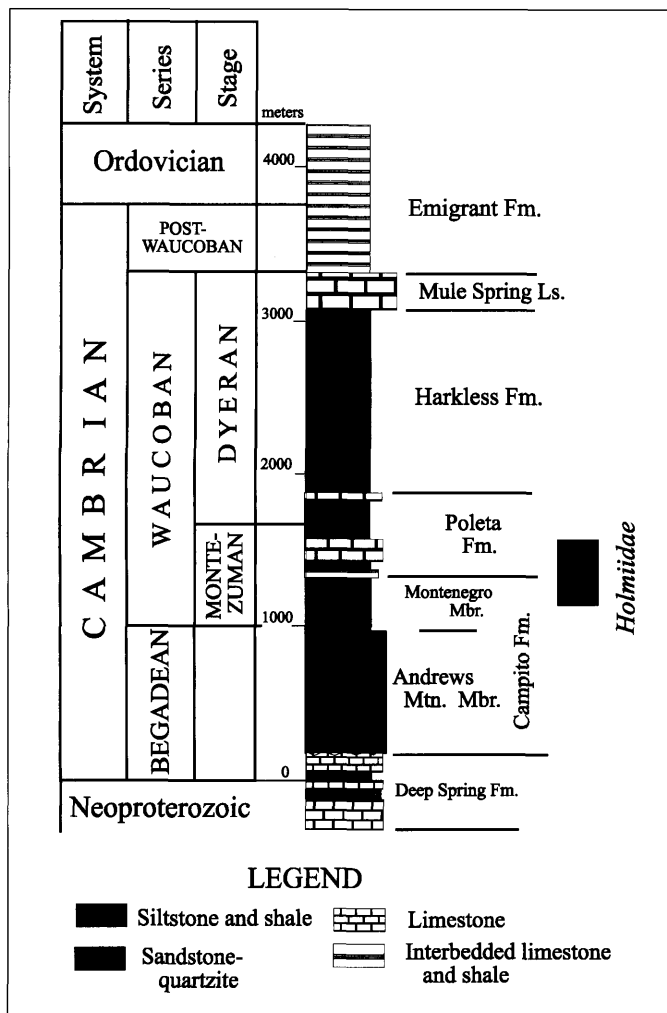
FIGURE 1—Composite stratigraphic section for Cambrian strata in Esmeralda County, Nevada, and composite range of holmiid trilobites (Albers and Stewart, 1972; McCollum, personal commun., 2002).
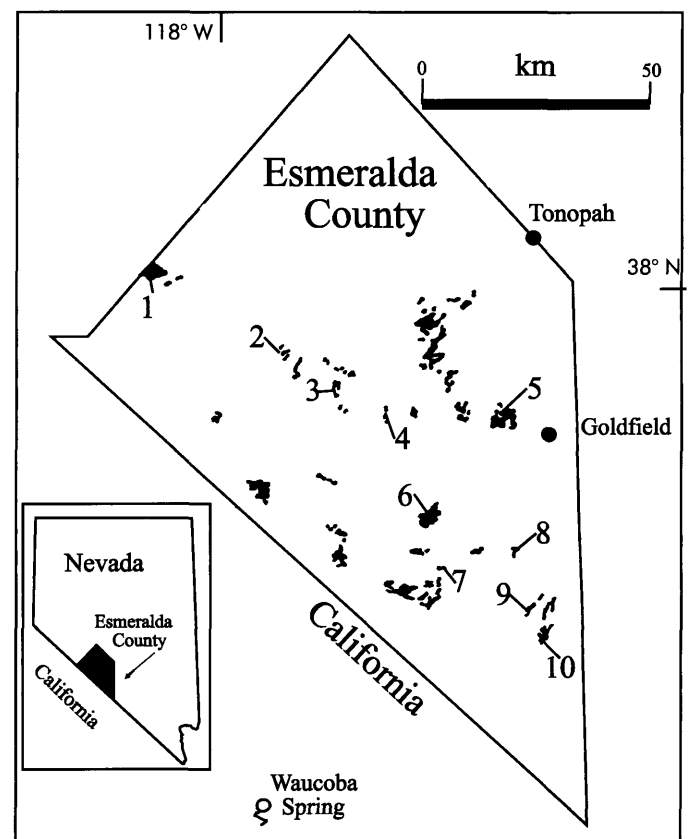

FIGURE 2—Location of stratigraphic sections and collecting sites in Esmeralda County, Nevada. Black areas are the outcrops of the Montenegro Member of the Campito Formation and the Poleta Formation from map by Albers and Stewart (1972). Numbers refer to specific sites or study areas: (1) Miller Mountain, (2) Fish Lake Valley, (3) Mineral Ridge, (4) Alcatraz Island, (5) Montezuma Range, (6) Barrel Springs (probable location), (7) Stewart's Mill, (8) east of Mount Jackson, (9) Gold Point, (10) Slate Ridge (see Appendix for details).

or absent in a complex of algal-archaeocyathan bioherms succeeded by the upper unit of oolitic grainstone (Rowland, 1981). The details of lower Poleta stratigraphy are still being studied.

The middle Poleta is 198 m thick in the Montezuma Range, and the bottom third is greenish gray shaly siltstone with occasional thin bioclastic carbonate beds. The middle third is siltstone with considerable sandstone and subordinate thin bioclastic carbonate beds also with several meter-scale micritic limestone units. The upper third has considerably more sandstone, some of which is calcareous, occasionally with distinct calcareous laminae. Trilobites are a major component of a varied fauna that is well preserved in the middle Poleta. The upper Poleta is 35 m of gray limestone.

For the discussions of trilobite ranges in this paper, the term "lower Montezuman Stage" refers to the lower part of the Montenegro Member terminating at the top of the carbonate-quartzite transgressive interval (Fig. 5). The upper 184 m of the Montenegro Member is termed "middle Montezuman." That part of the stage occurring in the Poleta Formation, a thickness of 222 m in the composite Montezuma Range section, is termed "upper Montezuman."

Biostratigraphy.—The holmiids of the Montezuman Stage range through most of the "*Nevadella*" Zone as defined by Fritz (1972), which comprises the middle and upper Montezuman (Fig.

5). When taxonomic studies of all the trilobites of the Montezuman Stage are completed, a revised biozonation of this interval may be recommended.

The lower Montezuman is characterized by fallotaspidid and related trilobites. Nevadiid and holmiid trilobites appear at the base of the middle Montezuman Stage, the latter as *Montezumaspis parallela* (Fritz, 1995) n. gen. followed quickly by *M. cometes* (Fritz, 1995), which together range through about 60 m of strata. *Esmeraldina rowei* (Walcott, 1910) appears about 26 m above the first appearance of *M. parallela*, and continues for 105 m. *Esmeraldina elliptica* n. sp. appears somewhat later than *E. rowei* and is rather uncommon (Fig. 5).

Grandinasus auricampus n. gen. and sp. and *G. patulus* n. sp. appear near the top of the middle Montezuman, 28 m below the base of the Poleta Formation in the Montezuma Range; *G. patulus* appears to be gone in the lowest unit of the Poleta while *G. auricampus* is common in the lowermost Poleta of the Gold Point area. *Grandinasus argentus* (Walcott, 1910) is fairly common in the middle shale unit of the lower Poleta in the Montezuma Range and elsewhere. *Holmiella falx* n. sp. also occurs in this shale unit of the lower Poleta. A form questionably referred to *G. auricampus* has been found at the top of the lower Poleta in the Gold Point area. Only a single questionable holmiid has been found in the middle Poleta.
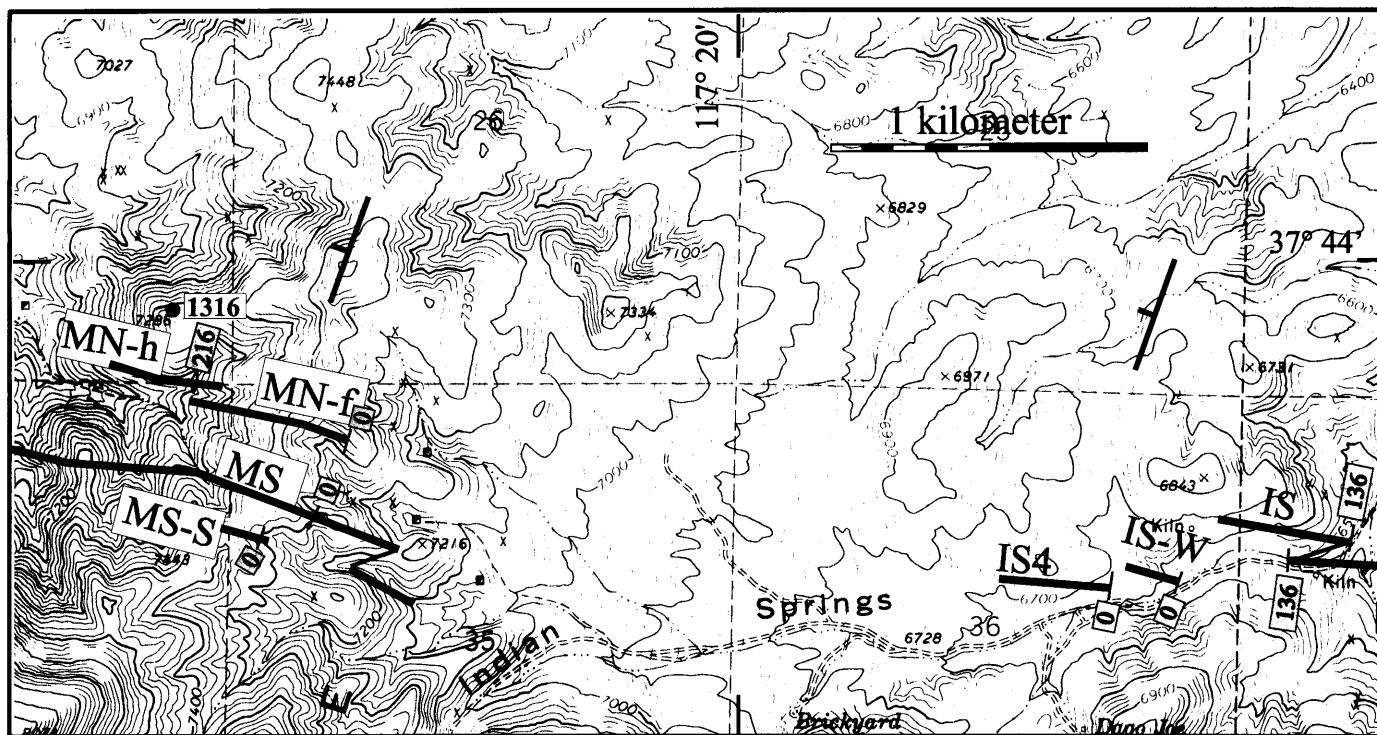
FIGURE 3—Locations of stratigraphic sections in the northern Montezuma Range, with locality 1316 and generalized dip of Cambrian strata. Topography from the U.S. Geological Survey Montezuma Peak Quadrangle, 7.5-minute series, 1970 edition. Base or key position shown on each section. Sections MN-f, IS, and IS-W measured by W. H. Fritz with JSH assisting.

Biofacies.—Three informal trilobite biofacies, a holmiid-dominated biofacies in the upper part of the Montenegro Member, a nevadiid-dominated mixed biofacies in the lower member of the Poleta Formation, and a nevadiid biofacies in the middle member of the Poleta, are suggested in this study. Few of the biostratigraphic collections that form the basis of this study are large enough for formal biofacies analysis (Ludvigsen et al., 1986), but counts of cephala in all collections from specific stratigraphic intervals provide some data for biofacies interpretation. Holmiid specimens comprise 60% of the trilobite fauna from 170 to 215 m in the composite Montezuma Range section (Fig. 5) increasing to 75% for the interval from 215 m to the top of the Montenegro, with nevadiids making up the rest of the trilobite fauna. This constitutes the holmiid-dominated biofacies which occurs in a relatively deep subtidal and dysaerobic mud bottom.

In the lower member of the Poleta Formation in the Montezuma Range, *Grandinasus* n. gen. constitutes 7% of the trilobite fauna which is dominated by nevadiids. *Holmiella* Fritz, 1972 appears with *Grandinasus* in other areas of Esmeralda County, and at Miller Mountain *Holmiella* is the only holmiid in the trilobite fauna. At the Gold Point, Slate Ridge and Fish Lake Valley sections, however, solenopleurids, corynexochids, and *Bradyfallotaspis* Fritz, 1972 are about as abundant as the associated holmiids, but nevadiids are still the predominant trilobites. This nevadiid-dominated mixed biofacies occurs in a relatively shallow, mixed carbonate-siliciclastic environment. Trilobites are occasionally common in the ribbon limestone and in the shaly middle unit of the lower member of the Poleta, but very rare, except as small fragments, in the carbonate grainstones.

In most of the lower part of the middle Poleta, the trilobites are almost exclusively nevadiids with a single holmiid? occurrence in a thin bioclastic limestone. This nevadiid-dominated biofacies occurs on a subtidal siliciclastic mud bottom (see also Bohach, 1997, p. 36).

Regional distribution.—Rocks of the "*Nevadella*" Zone of the Montezuman Stage are present along the western margin of Laurentia in many areas from northern Mexico (Stewart et al., 2002) to northwestern Canada. Outside the White-Inyo-Esmeralda County region, *Esmeraldina* Resser and Howell, 1938 has been noted in the Caborca region of Mexico (see *Discussion* of *Esmeraldina rowei*), the Cassiar Mountains of British Columbia (Fritz, 1978b, 1995), and in the Mackenzie Mountains (Fritz, personal commun., 2001). *Holmiella* is abundant in parts of the Sekwi Formation of the Mackenzie Mountains (Fritz, 1976, 1978a). In eastern Laurentia, Montezuman rocks are present in northern Greenland, but holmiids are not known there. Holmiids are the only olenelloid trilobites in Baltica, but they seem to represent a more advanced clade compared to the western Laurentian forms. Holmiids have also been reported from western Gondwana (Geyer and Palmer, 1995) and from Siberia (Palmer and Repina, 1997).

SYSTEMATIC PALEONTOLOGY

The terminology used in the descriptions follows the new trilobite volume of the *Treatise on Invertebrate Paleontology* (Whittington, 1997). The designations LA and L0 are used throughout for the frontal lobe of the glabella and for the occipital ring, respectively (Bergström, 1973; Whittington and Kelly, 1997, p. 321). The length of the glabella includes L0 in the descriptions. Thoracic segments and pleural spines are described using terminology proposed by Palmer and Repina (1993) and Palmer (1998a). Most of the trilobite material from the Montenegro Member of the Campito Formation is internal or external molds. Exoskeletal material is either absent or replaced by a mat of high-iron chlorite (Hood, personal commun., 1999). Little can be contributed to the understanding of the ontogeny of these holmiids. A few late-stage meraspides, generally defined by size, are described from siltstone surfaces from the Montenegro Member and limestone blocks from the Poleta Formation.
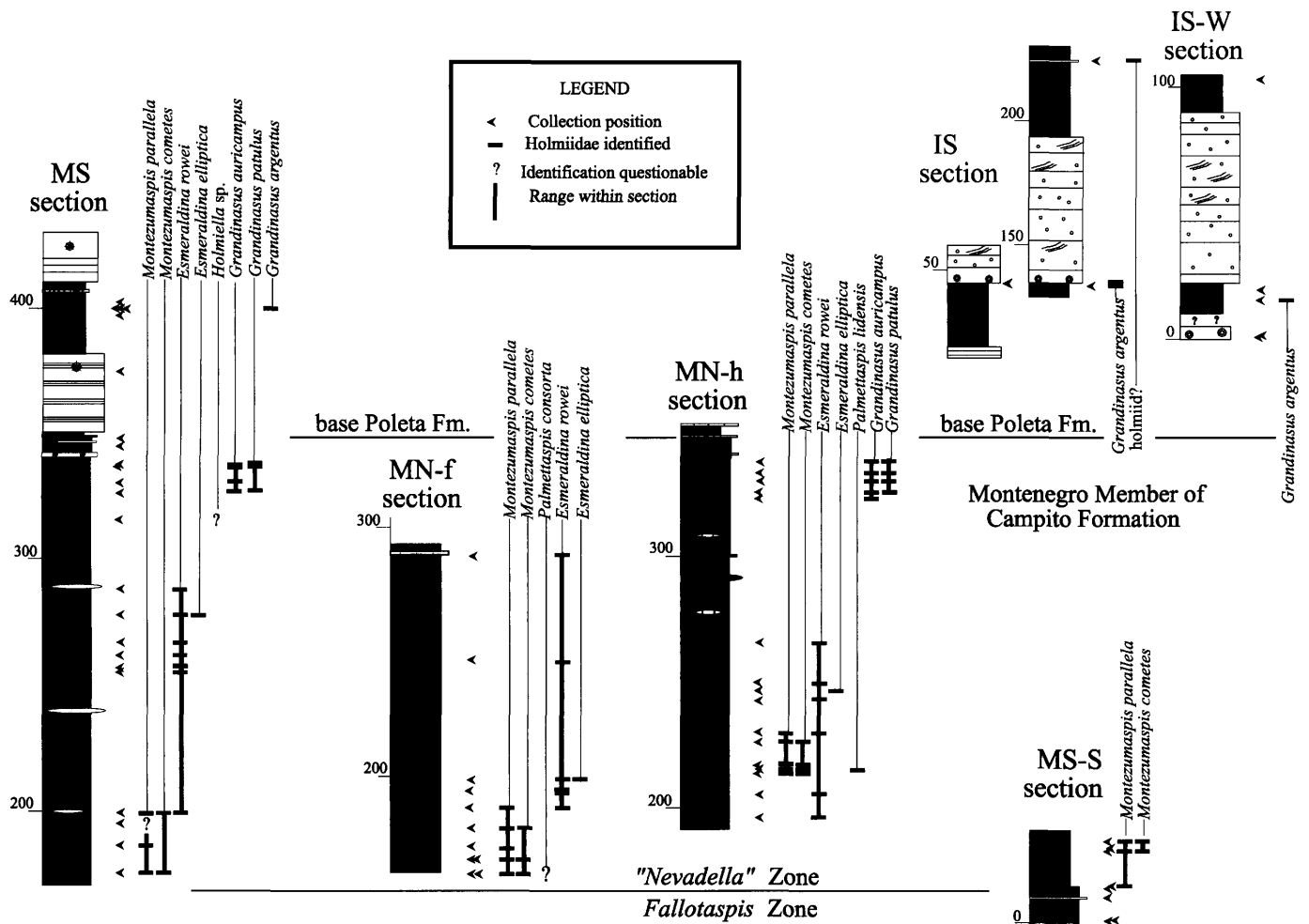
FIGURE 4—Stratigraphic sections in the Montezuma Range, Esmeralda County, Nevada, showing the positions of fossil collections and the occurrence of the various holmiid trilobites. See Figure 3 for the location of the individual sections and Figure 5 for lithologic legend.
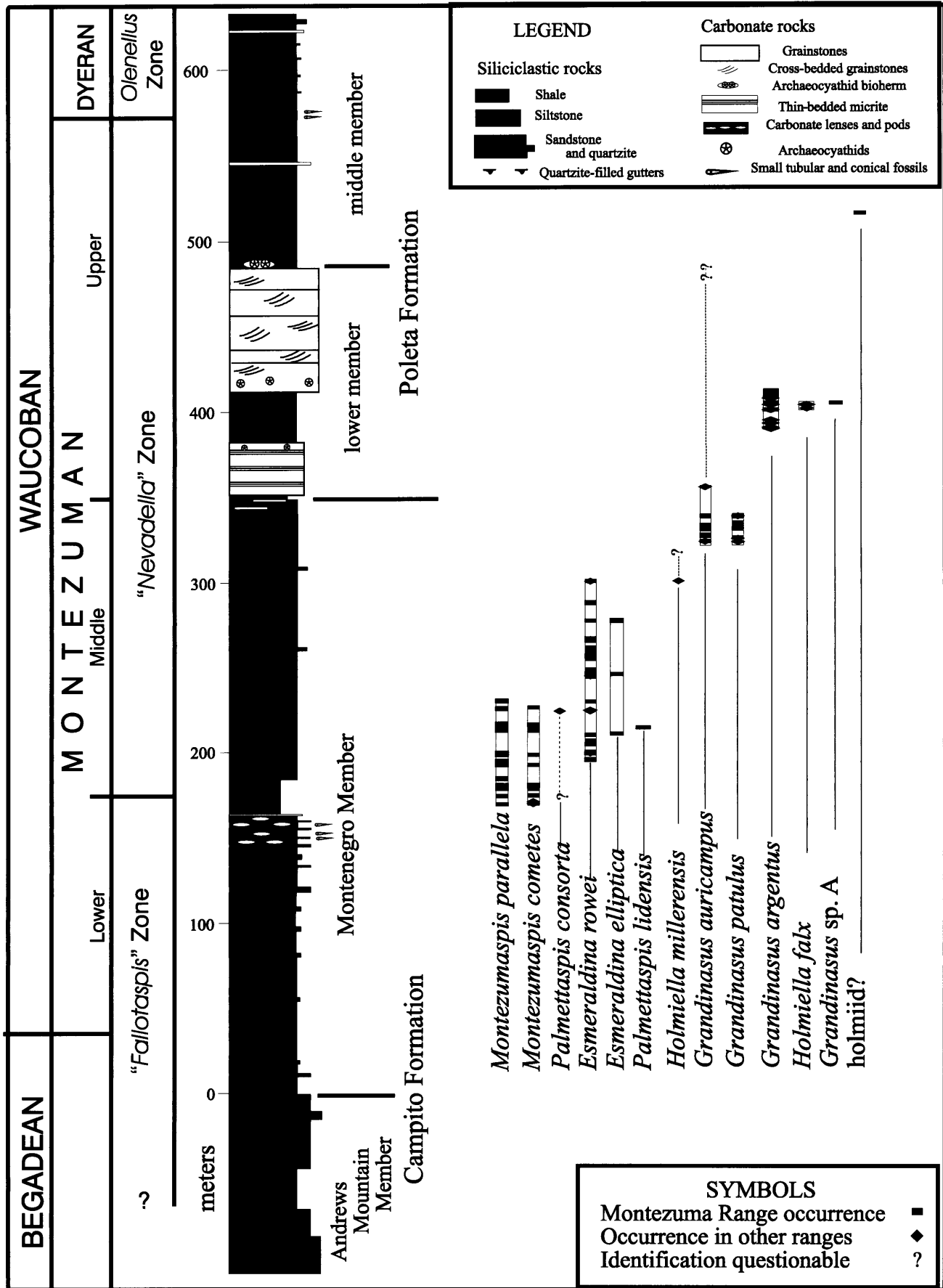
Illustrated specimens and key specimens are reposited in the collections of the Department of Paleobiology, National Museum of Natural History (USNM), Smithsonian Institution, Washington, DC, the University of California at Los Angeles (UCLA), and the Institute for Cambrian Studies reference and replica collection (ISC). The remainder of the biostratigraphic collections is housed in my personal collection.

Family HOLMIIDAE Hupé, 1953b

The concept and taxonomic history of the Holmiidae was reviewed by Lieberman (1999, p. 67–69). He restricts this family to *Holmia* Matthew, 1890, *Kjerulfia* Kiaer, 1917, *Schmidtiellus* Moberg *in* Moberg and Segerberg, 1906, *Palmettaspis* Fritz, 1995, *Esmeraldina*, and *Holmiella*, removing *Andalusiana* Sdzuy, 1961, *Callavia* Matthew, 1897, *Cambropallas* Geyer, 1993, *Elliptocephala* Emmons, 1844, and *Iyouella* Geyer and Palmer, 1995, which were included in the family by Palmer and Repina (1997). Lieberman (1999, p. 76) erected *Baltobergstroemia* with *Holmia mobergi* Bergström, 1973 as the type species, but Ebbestad et al. (2003) regard *Baltobergstroemia* as a junior synonym of *Holmia*.

Lieberman's (1999) cladistic studies suggest that *Holmia* is primitive with respect to the Laurentian holmiids *Palmettaspis*, *Esmeraldina*, and *Holmiella* (see also Lieberman, 1998, p. 63). This conclusion is not consistent with the biostratigraphy emerging from studies of the Montezuman trilobites (see Lieberman's reservations, 1999, p. 65–67) and it may result from his choice of *Wanneria walcottana* (Wanner, 1901) as outgroup for the analysis of the Holmiidae. Instead, the arrangement of the ocular lobes of Baltic and Moroccan holmiids (Geyer and Palmer, 1995), which have a wide ocular lobe with an ocular furrow and the inner band merging with the LA without an axial furrow, is interpreted as advanced compared with the arrangement of the simple ocular lobes of Laurentian holmiids, which are separated from the LA with a prominent axial furrow. Lieberman (1998, p. 77, character 14) remarks that this furrow is unique among olenelloids. Ocular lobes merged with LA and with an ocular furrow are found on younger olenellines (Palmer and Repina, 1997). Two new genera, *Montezumaspis* and *Grandinasus*, are described within Holmiidae.

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FIGURE 5—Composite range chart for the Holmiidae of the Montezuman Stage plotted against a composite stratigraphic column for the Montezuma Range.

LEGEND

Siliciclastic rocks

- Shale
- Siltstone
- Sandstone and quartzite
- Quartzite-filled gutters

Carbonate rocks

- Grainstones
- Cross-bedded grainstones
- Archaeocyathid bioherm
- Thin-bedded micrite
- Carbonate lenses and pods
- Archaeocyathids
- Small tubular and conical fossils

SYMBOLS
Montezuma Range occurrence ■
Occurrence in other ranges ◆
Identification questionable ?

Emended diagnosis.—Glabella straight-sided to somewhat constricted, mostly expanding forward, frontal lobe usually broad, rounded. Glabellar furrows usually curved, moderately incised, rarely complete across glabellar axis. S3 strongly curved and may be obsolete. Ocular lobes of Baltic holmiids are often wide with an ocular furrow, inner band merging with LA without axial furrow. Laurentian holmiids have unfurrowed ocular lobes separated from LA by axial furrow. Genal spine extends back at least to T4. Intergenal margin normally marked by spine behind the lateral margin of ocular lobe or somewhat abaxial of that point. Posterior border of cephalon from axial furrow to intergenal angle transverse or directed posteriorly. T3 generally unmodified. Anterior thoracic pleural spines weakly to strongly thornlike except in *Kjerulfia* and *Grandinasus*.

Discussion.—Many other characters diagnosed by others (Ahlberg et al., 1986; Palmer and Repina, 1997; Lieberman, 1999) differ among the taxa included in the Holmiidae. Details of glabellar furrows are often taphonomically modified. The length of ocular lobes is an ontogenetic variable (Palmer, 1957; Webster, 2003). The angle with the sagittal axis formed by a line between the most anterior point and the posterior tip of the ocular lobe varies between species. The ratio of the transverse width of the extraocular area to the width of the interocular area, the character of the extraocular area, and the character of the anterior and lateral borders are all variable among taxa. A revised character set for cladistic analysis is under consideration for a future study.

Genus MONTEZUMASPIS new genus

Type species.—*Palmettaspis parallela* Fritz, 1995.
Included species.—*Esmeraldina*? *cometes* Fritz, 1995.
Diagnosis.—Holmiid with preglabellar field. Glabella narrow, LA equal to or slightly wider than L0, S3 faint, L3 shorter (exsag.) than L2, L1, or L0 which are about equal, L0 with posterior axial spine, axial furrow uniform. Ocular lobes long. Extraocular area wide. Reticulate sculpture prominent on larger cephala. Thorax of 17 segments, T3 mildly amplipleural, pleural spines weakly thornlike to sentate. T13 has long, posteriorly directed axial spine; posterior to T13, thorax strongly tapered. Pygidium expands backward, posterior margin straight, posterolateral corners rounded. Axis triangular to subtriangular, not reaching posterior margin.

Etymology.—Named by combining Greek *aspis*, shield, with Montezuma for the Montezuma Range where several complete specimens were found.

Occurrence.—Lower middle Montezuman Stage in the Montezuma Range sections, in other mountain ranges of Esmeralda County, Nevada, and in the White-Inyo Range, Inyo County, California.

Discussion.—This genus accommodates two species that have primitive holmiidlike features and a long axial spine on T13. *Montezumaspis cometes* is closer to *Esmeraldina* in having small axial nodes or spines on each axial ring of the thorax, and with the axial spine on T13 being shorter than the telsonlike spine on *M. parallela*. Lieberman (1999) included *M. cometes* within *Palmettaspis*, but noting the relationship to be paraphyletic. This is addressed by moving this species to a new genus. *Montezumaspis* fits well within the diagnostic features of Holmiidae stated by Ahlberg et al. (1986) with the exception of the absence of an ocular furrow on all of the Great Basin holmiids. Lieberman (1999) assigns *Palmettaspis* (now *Montezumaspis*) and specifically *P. parallela* to the Holmiidae in spite of his emphasis that L3 must bulge laterally with respect to L1 to qualify as an olenelloid (Lieberman, 1998). This feature is variable on *M. parallela*. To accommodate *Montezumaspis* within the Holmiidae, two of Lieberman's (1999) other characters must be emended: T3 is somewhat amplipleural and thoracic axial rings lack anterolateral

lobes. Nevertheless, the assignment of *Montezumaspis* to Holmiidae is recommended herein.

Schmidtiellus from the Baltic region has a prominent axial spine on the thorax. The resemblance to *Montezumaspis* is enhanced by the relatively wide extraocular area and distinct longitudinal ridges on the thoracic axial rings of *S. reetae* (Bergström, 1973) anterior to the axial spine. Significant differences are the shape of the cephalon, the absence of a preglabellar field, the presence of a strong S3 furrow, and the presence of five thoracic segments behind the axial spine on *Schmidtiellus*. Bergström (1973, fig. 14d) described and illustrated the pygidium of *S. mickwitzi torelli* (Moberg, 1899), which has an evenly elevated axis with two apparent segments, narrow flat pleural fields, and tiny posterolateral spines. It is distinctly narrower than the pygidium of *Montezumaspis*.

MONTEZUMASPIS PARALLELA (Fritz, 1995)
Figures 6.1–6.14, 7.2, 7.3

Holmia rowei WALCOTT, 1910 (in part), p. 292–296, pl. 29, figs. 5, 6, non 1–4, 7–11.
Palmettaspis parallela FRITZ, 1995, p. 720–722, figs. 5.5, 5.6, 9.1–9.5; LIEBERMAN, 1999, p. 76–77 (coded), 84.

Emended diagnosis.—Sagittal length of preglabellar field equal to or slightly less than sagittal length of anterior border. Glabella typically parallel-sided with LA equal in width (tr.) to L0, anterior of LA rounded to somewhat pointed. L3 wider (tr.) than L2, S2 short and faint or absent at axial furrow. Ocular lobes gently curved, close to axial furrow. Narrow occipital spine arises as ridge on posterior half of L0. Axial rings of thorax have small longitudinal ridge on posterior half. Lateral margins of pleural spines backward-directed.

Description.—New material allows information to be added to the description provided by Fritz (1995).

Anterior border furrow shallow to indistinct laterally. Posterior margin slightly inclined back to intergenal spine then transverse to slightly inclined forward to genal angle which is laterally aligned with anterior half L0. Glabella parallel-sided, or with slight constriction at S2. LA often slightly tapered forward suggesting a broadly rounded point. Preglabellar field equal to or slightly less than sagittal length of anterior border. Glabellar furrows do not cross glabellar axis, but furrows often appear complete due to compaction. L1 and L2 of equal length (exsag.), L3 slightly to considerably shorter, L3 wider (tr.) than L2. S2 short, faint, or absent at axial furrow, S3 weak, arched forward. Width (tr.) between distal margins of ocular lobes about equal to glabellar length (sag.). Extraocular area more than twice as wide as interocular area; widest on large cephala. Anterior ocular line occasionally present. Sculpture of polygonal network observed on larger (15 mm or greater) cephala.

Hypostome longitudinally elongate, up to 11 mm in length, probably natant (Fig. 6.13) (Fortey, 1990). Anterior lobe of hypostome oval. Middle body oval. Anterior border not preserved. Posterior lobe is a substantial ridge surrounding posterior third of anterior lobe, middle furrow sharp laterally, shallowest at midline (Fig. 6.11). Posterior border flat, limited to transverse width of hypostome, posterolateral corners have outward-directed projections with a small spine at interior corner and small nodes along margin to external corner.

Anterior 13 segments of thorax narrow (tr.), as a unit nearly parallel-sided to slightly tapered on larger specimens, length (sag.) one-sixth more than cephalic length; prominent, broad-based spine on thirteenth segment; spine length over one-third and ranging to slightly more than full length of anterior part of thorax on largest specimens. Axis wide, one-fourth to two-fifths thoracic width including pleural spines, widest on larger specimens, with