Peters, Shanan E. 2003. Unpublished Ph.D dissertation. University of Chicago.

2 PALEONTOLOGY AND TAPHONOMY OF THE UPPER WEEKS FORMATION (CAMBRIAN, UPPER MARJUMAN, CEDARIA ZONE) OF WESTERN UTAH

2.1 Abstract

Twelve species of trilobites belonging to as many genera, one lingulide brachiopod species, *Lingulella sp.*, one aglaspid species, *Beckwithia typa*, and an undetermined lightly scleritized or soft-bodied arthropod-like animal were recovered in a quantitative collection from the upper Weeks Formation (Marjuman) in the House Range of western Utah. Previously described trilobite genera include, in order of abundance in the collection, *Cedaria, Modocia, Menomonia, Genevievella*, *Ammagnostus, Dresbachia, Norwoodia, Tricrepicephalus,* and *Weeksina.* Two new ptychopariid genera and species, *Nephalicephalus beebei* and *Selenocoryphe platyura*, were also recovered in the collection, as were two new ptychopariid species, *Modocia weeksensis* and *Norwoodia bellaspina*. Additionally the new ptychopariid genus and species *Gerospina schachti* is described from supplemental material. At least 12 other genera, mostly trilobites, are known to occur in the Weeks Formation but were not recovered in the quantitative sample.

The Weeks Formation fauna is very well preserved. Fossil orientation data and overall taphonomic state indicate little out-of-habitat transport of skeletal elements; 79 percent of the specimens recovered in an in situ collection consisted of articulated molts and complete exoskeletons. Sedimentary structures in the sample interval suggest episodic siliciclastic deposition in a carbonate mud-dominated environment located

near maximum storm wave base. Relative abundance data and evenness and diversity estimates are presented for a single quantitative sample.

2.2 Introduction

Richly fossiliferous Cambrian rocks are exposed in the central House Range of western Utah. Perhaps the most familiar assemblages from the House Range are the skeletonized and soft-bodied benthic marine faunas of the Wheeler Shale and Marjum Formation (e.g., Conway-Morris and Robison, 1988; Ubaghs and Robison, 1988; Briggs and Robison, 1984; Rigby, 1978; Janussen et al., 2002). Although these deposits have long been known to yield a diverse and well-preserved benthic assemblage, the fauna of the comparatively poorly exposed Weeks Formation remains understudied. Walcott (1908a, 1908b, 1916a, 1916b) published the first paleontological and stratigraphic descriptions of the Weeks Formation, which were later augmented by Deiss (1938) and by Bently (1958). More recently, Beebe (1990) completed an unpublished dissertation in which additional taxa were informally described from the Weeks Formation and more detailed taphonomic and biostratigraphic analyses were presented.

Here I summarize the systematic paleontology of a quantitative sample from the Weeks Formation and provide descriptions of several taxa that have not previously been formally described from this unit. I also present relative abundance data for the benthic assemblage that is based on collections made in 1999 from Walcott's original quarry location in the upper Weeks Formation at North Canyon, central House Range, Utah. This study is part of a larger-scale project on lower Paleozoic benthic community evenness and diversity. Preliminary taphonomic data are also presented.

2.3 Stratigraphic and Environmental Setting

Walcott (1908a) named and described the Weeks Formation on the basis of limited exposures in Weeks Canyon (now North Canyon), south-southeast of Marjum

Pass in the central House Range of Utah (latitude and longitude coordinates of study location: 39°12’57.3” N, 113°20’19.9” W). The unit consists of approximately 300 m of shallowing-upward, mostly thin-bedded lime mudstones with variable but limited amounts of sand-sized and finer siliciclastic sediments. Because of the regular and thinly bedded nature of the lime-mudstone of the Weeks Formation, a commercial decorative stone company has recently begun extensive excavation at Walcott’s original location in North Canyon. This activity has the positive effect of greatly increasing the quantity of fresh exposure. However, tremendous quantities of fossils are currently being sent to patios all over the country without paleontological inspection. Close cooperation between paleontologists and the commercial interests of the company would certainly be fruitful and would likely yield a number of important specimens and interesting insights.

The Weeks Formation conformably overlies outer-shelf shales and lime mudstones of the well-known and fossiliferous Marjum Formation and is overlain by shallow subtidal carbonates of the Big Horse Limestone Member of the Orr Formation. The Weeks is therefore transitional between deeper water facies of the outer shelf and shallower water sediments of the carbonate platform. The Weeks also represents the final infilling of the normal-fault-bound House Embayment (Rees, 1986). Palmer (1984) identified the Marjuman/Steptoean boundary within the Big Horse Limestone just south of North Canyon. The sample location is below this stage boundary and is within the *Cedaria* zone of the Upper Marjuman stage.

This study describes the benthic assemblage in a quantitative sample from the upper Weeks Formation, which consists primarily of thinly bedded (0.5-4.0 cm) silty lime-mudstone. The silt to fine quartz sand portion of this facies typically forms thin, reddish-orange, irregular laminae and parting surfaces between grey lime-mudstone with common peloids (Beebe, 1990). Small horizontal burrows occur on some bedding surfaces but bioturbation is, in general, limited in the Weeks and many other comparable Cambrian formations (Droser and Li, 2001; Droser and Bottjer, 1993).

Shallowing-upward, parasequence-scale packages on the order of 5-7 m are poorly exposed but evident at the sample location. The thickness of lime-mudstone beds and the ratio of lime-mudstone to silty-mud increase near the top of each package. Bedding surfaces in the upper 1-3 m of the parasequences are irregular and small-scale hummocky cross-stratification is present. The lower portion of each parasequence consists dominantly of thinly bedded limy silt and silty mud with thin and relatively continuous laminations (Figure 2.1). Throughout the unit, trilobites, lingulide brachiopods, and aglaspids are rare to abundant on many bedding surfaces.

The upper part of the Weeks Formation near the study location is interpreted to represent shallow subtidal environments located from just below maximum storm wave base to above maximum storm wave base. Silty laminations draping the lime-mudstone beds are inferred to represent storm-generated tempestites. Beebe (1990) suggested that the upper Weeks Formation preserves a shallow subtidal environment that was restricted and episodically hypersaline and that open-shelf trilobite taxa were either transported into the basin during storms or were only periodically present during brief episodes of normal marine conditions. While it is possible that circulation was periodically partially restricted by carbonate shoals during the deposition of the Weeks Formation, the composition and taphonomic condition of the fauna (see discussion below) indicate a normal marine assemblage that underwent little to no out-of-habitat transport.

2.4 Taphonomy and Relative Abundance

An unusually large number of trilobites in the upper Weeks Formation occur as articulated molts and completely articulated bodies with ventral sternites in place. In an in situ collection of 145 trilobite specimens from a 2m vertical interval and narrow horizontal interval (less than 3m) in the upper Weeks Formation at North Canyon (see coordinates above), 114, or 79 percent, of the specimens were articulated molts (e.g., Figure 2.3.5) or complete individuals. Only 13 isolated cranidia, 12 thoraxes consisting

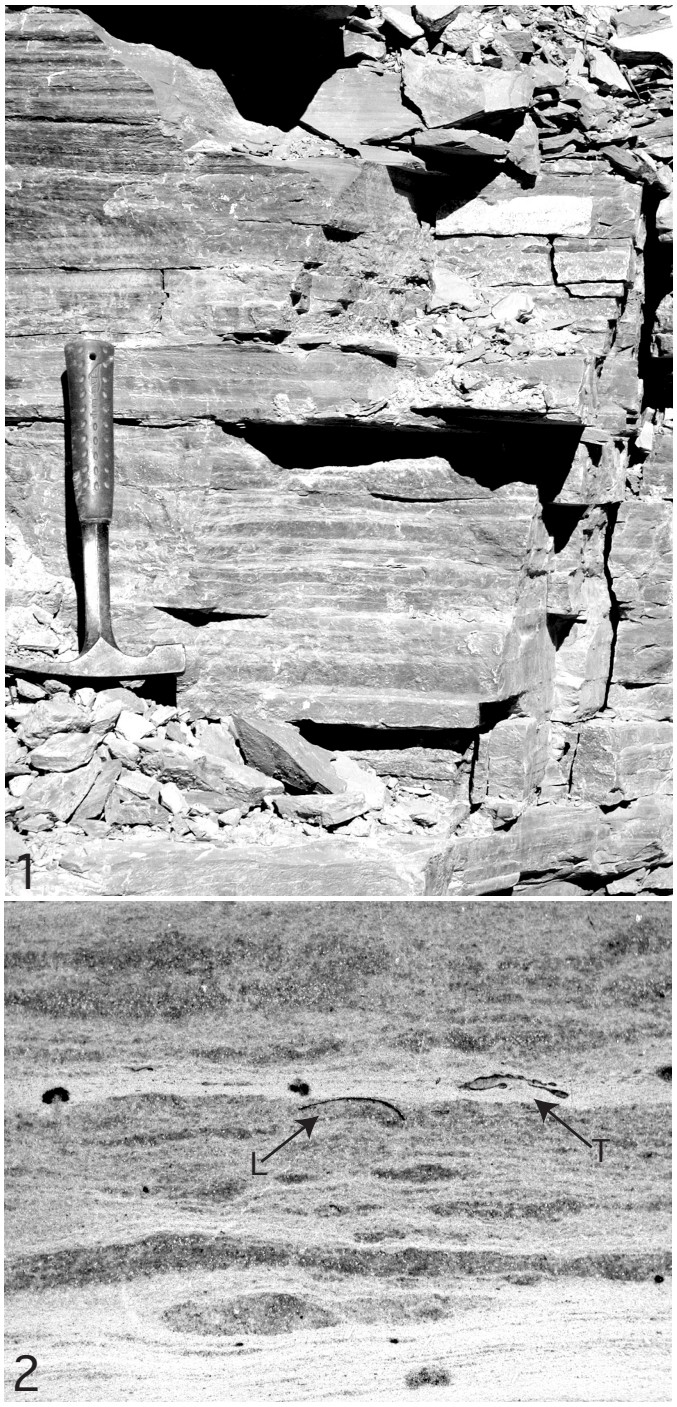

Figure 2.1: Weeks Formation. 1, outcrop view of upper Weeks Formation at sample interval in North Canyon, House Range, Utah. Hammer is 28 cm. 2, cross-section of cut and polished Weeks slab. Darker beds are lime mudstone, lighter intervals are silty lime-mud and fine quartz sand. A valve of *Lingulella* (L) and a cross section of a trilobite (T, probably *C. minor*) are visible.

of two or more articulated segments (single isolated thoracic segments were not counted but are also relatively rare), and six isolated pygidia were recovered. Although the frequency of articulated specimens may be inflated in these data because, on average, articulated specimens are larger and easier to see on fresh bedding planes, there is nevertheless a high proportion of articulated exuvia and individuals in the assemblage.

Most (95/114, or 83 percent) of the articulated molts and complete trilobites are preserved dorsal-side up on bedding surfaces. By contrast, 61 percent of the isolated cranidia, pygidia, and thoraxes are preserved in a dorsal-side up orientation. Commonly, only the ventral surface of the dorsal exoskeleton of articulated specimens is visible, giving the appearance that the individual was preserved dorsal-side down. However, the majority of such specimens have separated from the corresponding dorsal-side up ventral mold and are exposed on the bottom of bedding surfaces. Thus, the exposure of the ventral exoskeleton in museum collections should not be taken as evidence for a dorsal-side down burial orientation.

All of the trilobite specimens recovered in this study preserve calcitic exoskeletons that are weakly to moderately silicified. Partial pyritization and overgrowth by pyrite also occurs. Despite the exquisite preservation of exoskeletons, specimens in the field are usually extremely difficult to see or appear to be molds because they are commonly covered by thin silt drapes. Frequently, only the faintest outlines of a specimen can be seen on freshly exposed bedding surfaces and careful examination of fresh rock is required in order to recover most specimens. Preparation using an air-abrasive machine is necessary in order to identify the majority of specimens.

In addition to noting the completeness and dorsal-ventral orientation of each trilobite specimen in the in situ collection, compass bearings were taken. The orientation was measured along the anterior-posterior axis with the anterior end defining the azimuth. The headings of 114 articulated trilobite molts and complete individuals are summarized in a current-rose diagram in Figure 2.2. There is no strong current alignment of

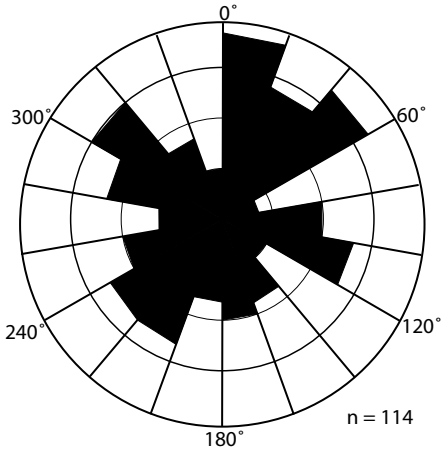

Figure 2.2: Current-rose diagram for articulated trilobite exuvia and complete individuals in an in situ collection covering approximately 1.5 vertical meters of section. Headings have not been rotated back to horizontal to account for orientation of beds (strike and dip of bedding: 019˚, 20˚ east). *N* = 114.

articulated trilobite molts or complete specimens. All of the 20 degree intervals shown in Figure 2 fall within the 95 percent confidence limits of a random assortment of 114 orientations based on the binomial distribution (expected number of specimens per bin is 6.3, 95 percent confidence limit is 1.5 to 11.1; Chi-square value is 16.7, df = 17, p = 0.472). If the compass headings are grouped into six 60 degree increments, then the northeast interval has significantly more specimens than expected based on a random assortment of orientations (expected number of specimens per bin is 19, 95 percent confidence limits are 11.2 to 27.8 based on binomial distribution; Chi-square value is 7.68, df = 5, p = 0.175). Thus, these data provide modest support for the hypothesis that currents preferentially aligned trilobite molts and carcasses to the northeast, but it is unlikely that periodic transport of carcasses into an inhospitable environment from adjacent, up-slope normal marine settings was the dominant mode of emplacement and preservation. The lack of strong current alignment and consistent dorsal-side up orientation is consistent with the hypothesis that the majority of carcasses underwent little to no transport before final burial and that the Weeks fauna represents a relatively undisturbed and minimally time-averaged autochthonous benthic assemblage (Kidwell

and Bosence, 1991). Recently shed exoskeletons and expired as well as live individuals were likely buried by silt and fine sand that was episodically transported into the House embayment during storms. The direct influence of storm currents at the sediment-water interface was probably minimal, except near the top of parasequences at the study section, where hummocky cross stratification is preserved. Overall taphonomic state (e.g., unabraded skeletons, little to no breakage of spines and other fine skeletal elements) also suggests that shells were not exposed to the water column for significant periods of time, possibly indicating episodic and relatively high rates of sedimentation.

In addition to bedding surfaces that contain abundant articulated trilobites, many bedding planes in the upper Weeks contain abundant well-preserved, small lingulide brachiopods. The brachiopods are somewhat patchily distributed on bedding surfaces, but densities can be as high as several hundred individuals per square meter. Trilobites are associated with the inarticulate brachiopods, but maximum trilobite density seldom corresponds to maximum brachiopod density. The distribution of the brachiopods on bedding surfaces gives no indication of current sorting or current-generated accumulation. However, if the lingulide brachiopods in the Weeks Formation were semi-infaunal, then the distribution of horizontal shells on bedding surfaces may indicate exhumation before final burial.

Abundance data for a whole-assemblage quantitative collection from the North Canyon quarry location are presented in Table 2.1. The assemblage is dominated by the lingulide brachiopod *Lingulella sp*. Among the trilobites, *Cedaria minor* is by far the most common constituent of the fauna. The Weeks Formation is rather unusual in comparison to many other Marjuman units because of its preponderance of well-preserved lingulide brachiopods and articulated trilobites. The evenness of the assemblage is, however, intermediate (near 0.5) and similar to many other Cambrian units of comparable age (Chapter 4).

Table 2.1: Absolute abundance and proportional abundance for macrobenthic marine fauna; agnostids were not included in whole assemblage analysis. *H*, Shannon-Weiner diversity index; *Essmin* and *Ess* evenness measure from Chapter 1; *J*, Pielou's evenness measure; *E* Buzas and Gibson's evenness index; *D*, Simpson's dominance index.

Taxon	Absolute Abundance	Proportional Abundance
Lingulella sp.	282	0.576
Cedaria minor	141	0.288
Modocia weeksensis	49	0.100
Menomonia semele	5	0.010
Genevievella granulatus	4	0.008
Nephalicephalus beebei	3	0.006
Beckwithia typa	2	0.004
Dresbachia amata	1	0.002
Norwoodia bellaspina	1	0.002
Selenocoryphe platyura	1	0.002
Tricrepicephalus teres	1	0.002
Weeksina unispina	1	0.002
(*Ammagnostus beltensis*	4	----)
n = 491	s = 12	H = 1.11
Essmin = 0.58	Ess = 0.63	J = 0.45
E = 0.25	D = 0.42	

2.5 Systematic Paleontology

All of the specimens described in this study were collected from a single section of the upper Weeks Formation in North Canyon, central House Range, Utah. Several of the new names proposed herein were first put forth by the late Matthew Beebe in an unpublished Ph.D. dissertation (Beebe, 1990) and have been in informal usage since then. I follow many of Beebe's precedents throughout this section and it is to him that I dedicate my efforts. Illustrated specimens are deposited at The Field Museum of Natural History (FMNH) in Chicago, Illinois or at the National Museum of Natural History (NMNH). Morphological terminology used follows Whittington (1997).

Order Ptychopariida Swinnerton, 1915

Family Cedariidae Raymond, 1937

Genus Cedaria Walcott, 1924

Type species.—*Cedaria prolifica* Walcott, 1924, p. 55, pl. 10, fig. 6.

Discussion.—Palmer (1962) provides the concept of *Cedaria* followed here.

Cedaria minor (Walcott, 1916)

Figure 2.3.1-3.5

Asaphiscus? minor Walcott, 1916b, p. 388-389, pl. 61, figs. 3a-b.

Cedaria (Walcott) Robison, 1987, fig. 13; Fortey, 1990, pl. 1, fig. 3.

Cedaria aff. cf. *C. gaspensis* Rasetti; Wilson p. 269, pl. 24, fig. 20.

Cedaria prolifica (Walcott) Robison, p. 59, figs. 14.8, 26.3 [lower].

Cedaria minor (Walcott) Resser, 1935, p. 19-20; Shimer and Shrock, 1944, p. 621, pl. 264, figs. 1-2; Robison, 1960, p. 18, pl. 1, fig. 16; Palmer, 1962, pl. 6, fig. 13; Pratt, 1992, p. 80-81, pl. 30, figs. 5-18; Whittington, 1992, p. 122, pl. 69; Babcock, 1993, fig. 3.6.

Description.—Body nearly isopygous. Cranidium gently convex transversely and sagittally. Glabella well defined by narrow axial and preglabellar furrows, tapered forward, rounded anteriorly; three pairs of weakly developed lateral glabellar furrows; occipital furrow distinct. Preglabellar field approximately 1.7 times longer (sagittal) than anterior border, which is of nearly constant width around cephalon; defined by distinct border furrow. Palpebral lobes semicircular, approximately 30 percent glabellar length (sagittal) and opposite glabellar midlength; palpebral furrows indistinct; fixigena width (transverse) at palpebral lobe approximately 47 percent maximum glabellar width (transverse). Anterior facial suture divergent just anterior of eyes, becoming parallel near border furrow and slightly convergent at margin; farthest abaxial position of facial suture

occurs at intersection with border furrow. Posterior fixigena narrow (exsagittal), slightly posteriorly angled. Posterior section of facial suture cedariidiform

Librigena with semicircular notch on inner margin, posterior of ocular area and anterior of sharp cusp at proximal base of genal spine. Librigenal field approximately 2.4 times as wide (transverse) as lateral border. Posterior section of facial suture intersecting lateral border furrow anterior of the junction between the lateral and posterior border furrows. Genal spine extends to fifth or sixth thoracic segment.

Hypostome elliptical, strongly convex, small, one-half length of glabella and slightly over one-half glabellar width. Anterior and posterior border narrow. Single pair of simple, short anterior wings; posterior margin rounded and lacking wings.

Thorax with seven uniform segments. Pleural lobes wider than axial lobe, which tapers posteriorly. Pleurae with distinct pleural furrows that terminate in a point before reaching pleural tips, which form broad, short, posteriorly reflected spines.

Pygidium large, approximately 72 percent cranidium length (sagittal), semicircular; seven axial rings. Axial lobe distinct, tapers posteriorly to rounded termination at inner margin of border. Axial rings becoming less distinct posteriorly. Pleural area with three to four interpleural furrows, prominent near anterior but becoming less distinct posteriorly. Border distinct, flat, and wide, widest along posterior margin; border approximately 30 percent of the width of the anterior width of the pleural field (transverse).

Occurrence.—*C. minor* occurs from 200 m above the base of the Weeks Formation (Beebe 1990) to the lower 15 m of the overlying Big Horse Limestone Member of the Orr Formation (Eby 1981). Also known from the Rabbitkettle Formation in the Mackenzie Mountains of Canada (Pratt, 1992), and from Greenland (Robison, 1987; Babcock, 1992).

Discussion.—This taxon is numerically dominant in the upper Weeks Formation. Aggregations of articulated specimens are commonly observed on bedding surfaces. The

Figure 2.3: 1-5, *Cedaria minor* (Walcott); 1, dorsal views of articulated exoskeleton (FMNH PE57111), X3.8; 2, dorsal exoskeleton of articulated exuvium, free cheeks are positioned over the left side of the thorax (FMNH PE57112), X3.3; 3, ventral exoskeleton showing hypostome (FMNH PE57113), X3.1; 4, dorsal views of articulated exoskeleton (FMNH PE57114), X2.7; 5, aggregation of articulated individuals, articulated molts, and isolated parts (FMNH PE57115), X1.3; 6, *Weeksina unispina* (Walcott), dorsal view, thorax slightly disarticulated and displaced laterally (FMNH PE57116), X4.4; 7-10, *Gerospina schachti* n.gen n.sp; 7, dorsal view, (FMNH PE57117) X3.4; 8, same as 7 but negative image to show additional detail; 9, detail of cranidium of same, X5.2; 10, anterior-lateral view of same, X4.1; 11, dorsal view of partial exoskeleton (NHNH 437968), X3.7.

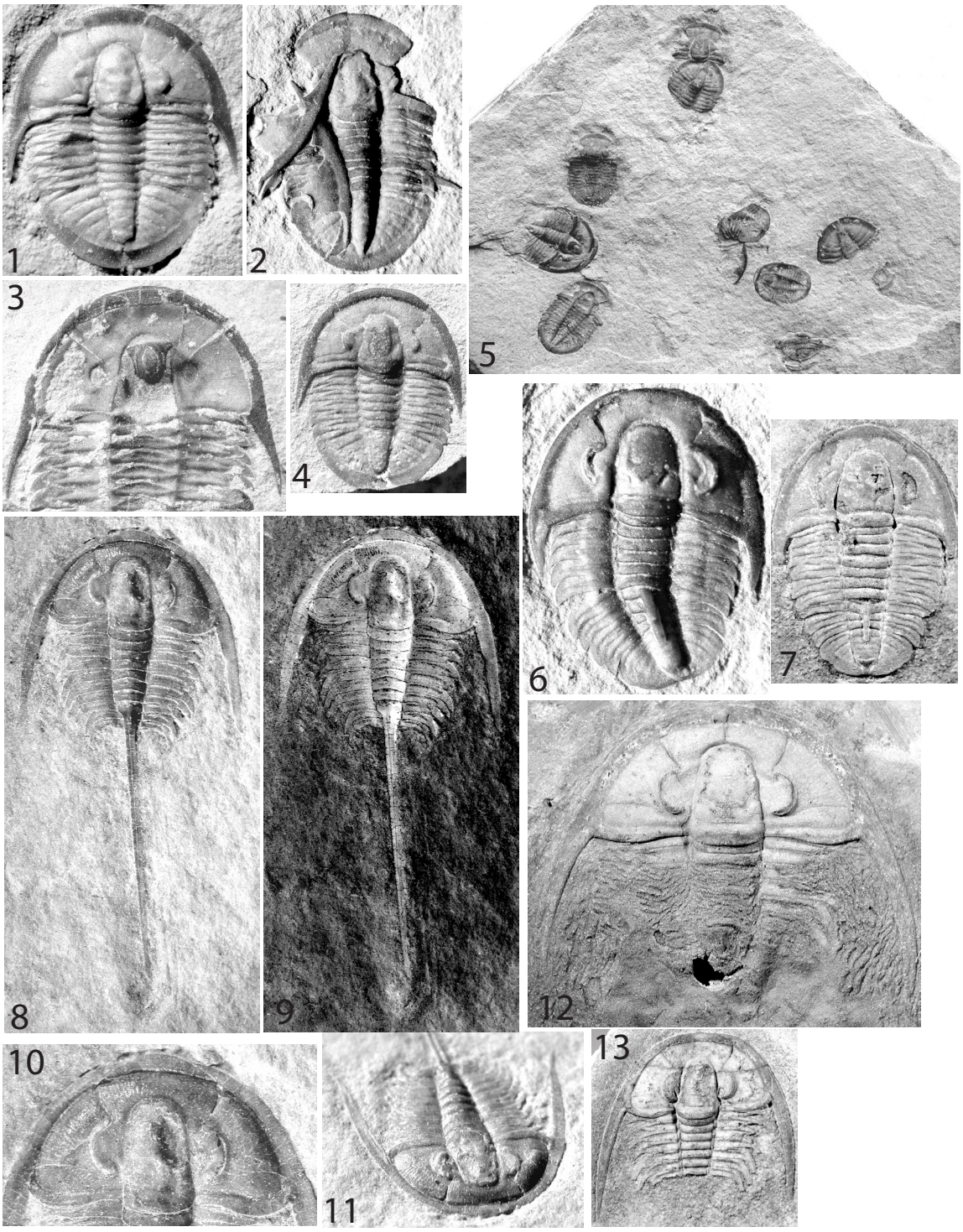
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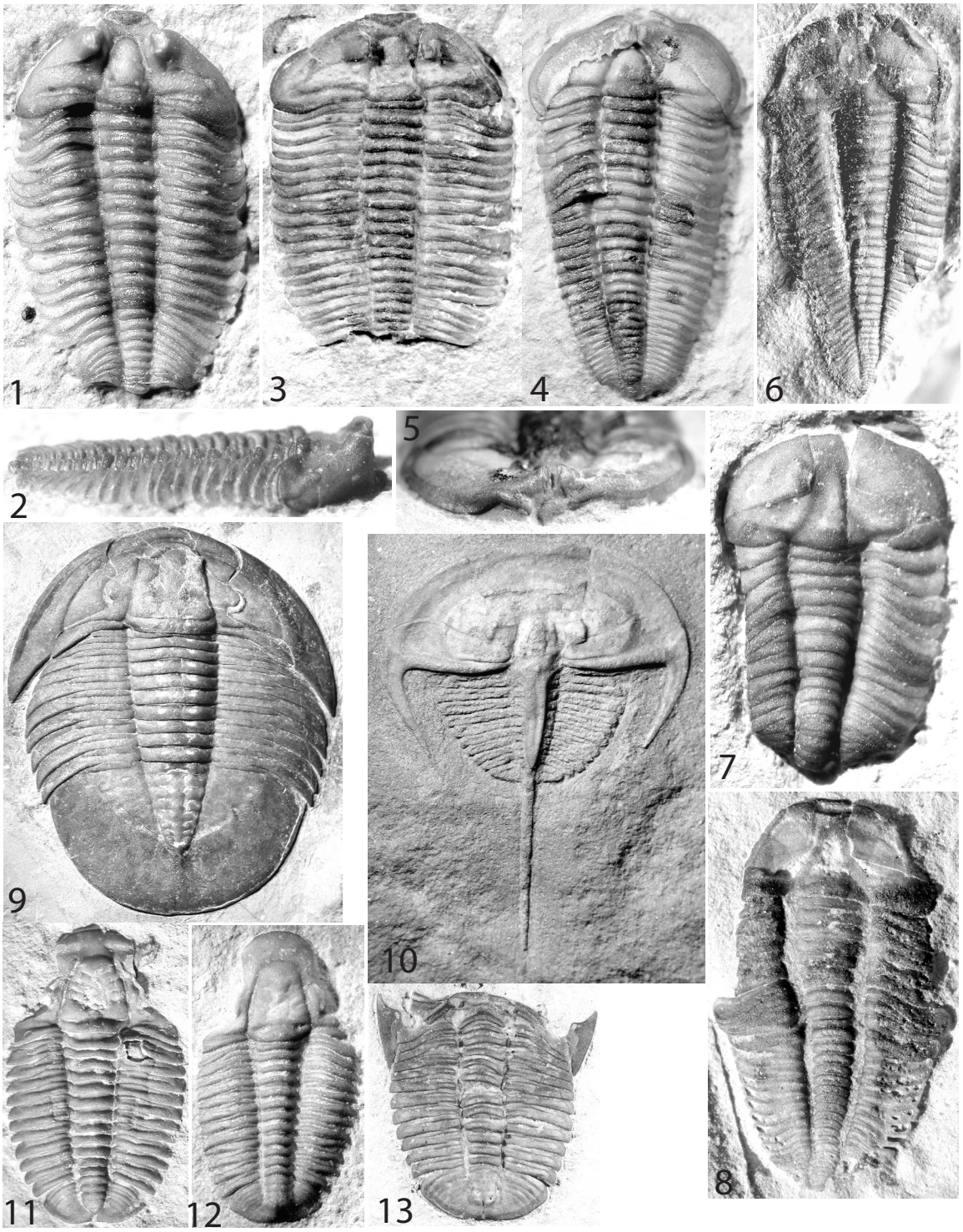
Figure 2.4: 1-3, *Menomonia semele* (Walcott); 1, dorsal view of articulated exoskeleton, (FMNH PE57118), X6.6; 2, right-lateral view of dorsal exoskeleton shown in 4.1, X6.5; 3, dorsal view of articulated exoskeleton (FMNH PE57119), X4.5; 4-5 *Dresbachia amata* Walcott, (FMNH PE57120); 4, dorsal view of articulated exoskeleton, X4.2; 5, frontal view of cephalon showing slight dorsal deflections of margin, X5.9; 6-8, *Nephalicephalus beebei* n.gen n.sp; 6, dorsal view of articulated exoskeleton, (FMNH PE57121), X3.1; 7, dorsal view of articulated exoskeleton, (FMNH PE57122), X6.3; 8, dorsal view of articulated exoskeleton, (FMNH PE57123), X4.6; 9, *Selenocoryphe platyura* n.gen n.sp, dorsal view of articulated exoskeleton, (USNM 437980), X1.6; 10, *Norwoodia bellaspina* n.sp, dorsal view of articulated exoskeleton, (USNM 437971), X4.0; 11-13, *Modocia weeksensis* n.sp; 11, dorsal view of articulated exoskeleton, (FMNH PE57124), X2.1; 12, dorsal view of articulated exoskeleton, (FMNH PE57125), X2.8; 13, dorsal view of articulated exoskeleton with cephalon bent under thorax to expose ventral surface of genal spines, (FMNH PE527126), X1.8.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average size of specimens from the upper Weeks is approximately one centimeter, though specimens up to nearly three centimeters were recovered.

Family Lonchocephalidae Hupé, 1953

Genus Weeksina Resser, 1935

Type species.—*Asaphiscus? unispinus* Walcott, 1916b, p. 389, pl. 61, fig. 1.

Weeksina unispina (Walcott, 1916)

Figure 2.3.6

Asaphiscus? unispinus Walcott, 1916b, p. 389, pl. 61, fig. 1.

Weeksina unispina (Walcott) Resser, 1935, p. 45.

Description.—Cranidium convex transversely and sagittally with elongate, parallel-sided to slightly tapering forward, anteriorly-rounded glabella; axial and preglabellar furrows deep and distinct; three pairs of variably developed but generally weak lateral glabellar furrows reaching axial furrows and inward-backward curved. Occipital furrow straight and distinct; occipital ring modestly broader than thorax segments and posteriorly convex. Preglabellar field less than half the length of the glabella; preglabellar field separated from slightly upturned anterior border by well-defined border furrow. Palpebral lobes distinct, large, lunate, approximately centered along length of glabella and approximately one-half the length of the glabella; ocular furrow curved and distinct; eye ridges poorly developed to absent. Facial sutures opisthoparian; posterior sections nearly straight and posteriorly deflected; anterior sections divergent just anterior of eyes but curve medially to become convergent near exsagittal portion of preglabellar field; anterior suture lines intersect frontal margin near anterior projection of axial furrows.

Genal spines straight, extending to approximately fifth thorax segment. Librigenal field slightly convex, lateral border approximately 22 percent posterior width (transverse)

of librigenal field. Posterior section of facial suture intersects border furrow at or just anterior of junction between lateral and posterior border furrows.

Thorax with 10 or 11 segments; eighth segment bears thin, rounded axial spine approximately three-quarters length of glabella. Axial lobe transversely strongly arched, well defined by moderately deep axial furrows. Pleural lobes less transversely convex and only slightly wider (transverse) than axial lobe. Pleural furrows moderately distinct, not reaching pleural tips. Pleural termini distinct, slightly pointed and posteriorly reflexed into short spines.

Pygidium sagitally and transversely slightly convex; micropygous. Pygidial length (sagittal) approximately three-quarters glabellar length; anterior pygidial width (transverse) approximately 1.75 times posterior glabellar width (transverse). Segmentation becoming obsolete posteriorly but of at least four segments. Axial region prominent, strongly convex (transverse), and extending nearly to posterior border. Pleural regions slightly convex, approximately 40 percent wider (transverse) than axial lobe, with four faint pleural furrows becoming obsolete near broad, flat border; posterior axial margin of border with shallow, anteriorly directed depression that meets axial lobe.

Occurrence.—Rare species known only from the mid to upper Weeks Formation (Marjuman).

Discussion.—This taxon can be confused with much more common *C. minor* in the field as it is in the same size range and of roughly similar outline and form. The cephalon of articulated specimens is frequently posteriorly displaced and obscures the first thorax segment, giving the appearance that the axial spine originates from the seventh segment.

Genus Gerospina new genus

Type species.—*Gerospina schachti* new species by monotypy.

Diagnosis.— Palpebral lobes large, approximately 60 percent glabellar length (sagittal), lunate. Glabella slightly tapered forward, truncate. Preglabellar field prominent,

approximately 25 percent glabellar length (sagittal) and sagittally convex. Posterior area of fixigena exsagittally expanded and lobe-like, very distinct from posterior limbs of *W. unispina*, which bears many similarities to this genus. Posterior sections of facial sutures intersect border anterior of genal angle then curve posteriorly to intersect margin behind genal angle. Cephalic border wide, of uniform width and flat. Genal spines extend to anterior portion of pygidium, same width as cephalic border and flattened. Eighth thoracic segment bears flattened spine that is greater than total length of body. Pleurae tapering to form prominent posteriorly directed spines. Micropygous, but pygidium not preserved in type specimen.

Etymology.—After the Latin *gero*, to bear or carry and *spina*, spine; in reference to genal and axial spines that are longer than the body and seem to weigh heavily on this taxon.

Discussion.—This genus shares a number of characters with *Weeksina*, including large palpebral lobes, a very slightly tapering glabella with a broad preglabellar field, and an axial spine originating on the eighth thoracic segment. It is smaller than most *Weeksina* specimens, the type specimen being 8 mm (exclusive of the axial spine, which is slightly longer than length of body).

GEROSPINA SCHACHTI new species

Figure 2.3.7-3.12

Diagnosis.—Same as genus.

Description.—Cephalon semicircular excluding genal spines; cranidium convex transversely and sagittally. Glabella distinct, slightly tapered forward, anteriorly-rounded, truncate. Axial furrows moderately deep and distinct. Lateral glabellar furrows indistinct to obsolete. Preglabellar field gently convex, with anastomosing caecae, approximately 25 percent length (sagittal) of glabella. Palpebral lobes large, lunate, approximately 60 percent of glabellar length, located near midpoint of glabella. Palpebral area of fixigena approximately 42 percent of basal glabellar width. Eye ridges broad and

poorly defined. Occipital furrow shallow, straight. Occipital ring slightly posteriorly convex and approximately 24 percent length (sagittal) of glabella. Border furrow narrow and well defined. Border distinct, planar to slightly convex, broad, approximately 20 percent glabellar length (sagittal), of equal width around cephalon. Posterior area of fixigena long, lobe-like, distally expanded (exsagittal) to nearly one-half glabellar length (sagittal). Posterior facial sutures cedariiform, curved slightly anteriorly just posterior of eyes; intersect lateral border anterior of genal angle and intersect lateral margin near genal angle at base of genal spine. Anterior facial sutures slightly divergent anterior of eyes; rounded anteriorly to be convergent and intersecting margin near sagittal line.

Librigenal field roughly trapezoidal, with anastomosing caecae. Genal spines long, nearly extending to pygidium and approximately 1.2 times cephalic length.

Thorax with 10 segments, the axial lobe of the eighth segment bears a prominent, broad, somewhat flattened spine with expanded base. Axial spine approximately 2.5 times length (sagittal) of cranidium and longer than total length of body. Thorax moderately tapered posteriorly and slightly convex transversely. Anterior pleurae terminate in short, laterally directed spines. Posteriorly, pleural spines become longer and progressively more posteriorly deflected. Anterior pleural furrows distinct, directed laterally, and wide (exsagittal). Posterior pleural furrows similar but are curved posteriorly. Pleural furrows nearly reaching pleural spine tips.

Pygidium unknown on types but on the basis of privately held specimens is known to be small, approximately one-half length (sagittal) of glabella and nearly same width (transverse) as basal glabella.

Etymology.—After Robert Schacht Sr. and Robert Schacht Jr., finder and donor, respectively, of the holotype which is one of only several nearly complete specimens known.

Types.— Holotype FMNH PE57117. Paratypes NMNH 437949, 437968.

Measurements.— Holotype; total body length (sagittal), including long thoracic spine 17.4 mm. Body length excluding spine 7.5 mm (sagittal). Maximum cranidial width 7.5 mm (transverse). Cranidial length (sagittal) 4.0 mm.

Occurrence.—Presently known only from the upper Weeks Formation (Marjuman) in North Canyon, central House Range, Utah.

Discussion.—This species is very rare in the upper Weeks and only a few completely articulated specimens are known. All of these have been found by amateur and/or commercial fossil collectors and are currently in private collections.

Family Menomoniidae Walcott, 1916

Genus Dresbachia Walcott, 1916

Type species.—*Dresbachia amata* Walcott, 1916a.

Discussion.— Stitt and Perfetta (2002) provide the concept of *Dresbachia* followed here.

Dresbachia amata Walcott, 1916

Figure 2.4.4-4.5

Dresbachia amata Walcott, 1916a, p. 167, pl. 26, figs. 5-5c; Shimer and Shrock, 1944, p. 623, pl. 264, fig. 22; Lochman, 1950, p. 338-339, pl. 48, figs. 11-14; Rasetti, 1965, p. 61-62, pl. 8, figs. 1-4; Stitt and Perfetta, 2000, p. 217, fig. 10.

Description.—Cephalon short (sagittal) and wide (transverse). Cranidium smooth, convex. Glabella strongly tapered forward, sub-triangular, rounded anteriorly. Axial furrows moderately deep, distinct. Three pairs of short, indistinct lateral glabellar furrows. Occipital furrow shallow, transverse; occipital lobe finely granular, slightly posteriorly convex. Preglabellar field very narrow (transverse), flat. Anterior border is a narrow, small rim. Palpebral area of fixigena reduced to nearly vertical strips located in front of glabella near midline, bracketing narrow preglabellar field. Palpebral lobes short, less than one-third glabellar length (sagittal) and elevated above body. Posterior

area of fixigena broad, convex, slightly posteriorly deflected. Posterior border furrow straight (transverse), moderately deep and prominent. Posterior border convex, broadest marginally. Posterior sections of facial sutures slightly sinuous, gonatoparian. Genal angle obtuse, rounded. Anterior sections of facial sutures closely spaced, slightly divergent, intersecting margin at nearly right angles.

Librigena gently convex, roughly crescent-shaped, with prominent eye stalk. Lateral border furrow indistinct. Anterior margin of librigena with two slight, exsagittal dorsal deflections; deflection prominent when viewed from anterior margin (Fig. 4.5).

Thorax tapers posteriorly with approximately 32 segments; posterior segments becoming very small sagittally and transversely. Axial lobe finely granular, convex, tapering; axial furrows moderately deep and distinct. Pleural lobes convex, of nearly same width (transverse) as axial lobe. Pleurae with short, moderately deep and distinct pleural furrows; wide near axial furrows, tapering distally and terminating in fine points in anterior half of pleurae; anterior furrows extend approximately one-half pleural width (transverse), posterior furrows one-third.

Pygidium minute; not visible on illustrated specimen.

Occurrence.— Rare in the upper Weeks Formation. Also known from the Eau Claire and Franconia Formations of Wisconsin and Minnesota (Walcott, 1916a), and the Deadwood Formation in South Dakota (Stitt and Perfetta, 2000).

Discussion.— One articulated specimen was recovered in the quantitative collection. The distribution of this taxon within the Weeks is unknown.

Genus Menomonia Walcott, 1916

Type species.—*Conocephalites calymenoides* Whitfield, 1878, p. 52.

Discussion.— Pratt (1992) provides the concept of *Menomonia* followed here.

MENOMONIA SEMELE (Walcott, 1916)

Figure 2.4.1-4.3

Millardia semele WALCOTT, 1916a, (part), p. 166, pl. 28, fig. 3, a-b (only; 5c = *Nephalicephalus beebei* n.gen n.sp); RESSER, 1938b, p. 35.

Millardia avitas WALCOTT, 1916a, p. 165, pl. 28, fig. 5; LOCHMAN, 1938a, p. 469, pl. 56, fig. 27; LOCHMAN, 1940, p. 44, pl. 4, figs. 39-42.

Millardia magnagranulata LOCHMAN, 1938b, p. 84, pl. 18, fig. 2.

Acrocephalites multisegmentus WALCOTT, 1916a, (part), p. 180, pl. 24, fig. 5a (only).

Densonella semele (WALCOTT) SHAW, 1952, p. 477; ROBISON, 1960, p. 26, pl. 2, fig. 4.

Densonella sp. PALMER, 1954, p. 742, pl. 83, fig. 7.

Menomonia buttsi RESSER, 1938a, p. 88, pl. 10, fig. 39; SHIMER and SHROCK, 1944, p. 621, pl. 265, fig. 35.

Menomonia avitas (WALCOTT) SHIMER and SHROCK, 1944, p. 627, pl. 65, fig. 33-34

Menomonia lochmanae RESSER, 1938b, p. 36.

Menomonia calymenoides (WHITFIELD) WALCOTT, 1916a, p. 162, pl. 26, fig. 4; SHIMER and SHROCK, 1944, p. 627, pl. 265, fig. 36; TASCH, 1951, p. 300-301, pl. 47, fig. 7; ROBISON, 1960, p. 27, pl. 2, fig. 5.

Menomonia semele (WALCOTT) RESSER, 1938a, p. 35; LOCHMAN AND DUNCAN, 1944, p. 135-136, pl. 14, figs. 10-13; SHIMER AND SHROCK, 1944, pl. 265, figs 37-38; RASETTI, 1946, p. 458, pl. 70; PRATT, 1992, p. 78, pl. 29, figs. 1-12.

Description.—Cranidium convex transversely and sagittally, bearing many tubercles. Glabella strongly tapering forward, rounded anteriorly, convex; well defined by deep axial furrows and moderately deep preglabellar furrow. Lateral glabellar furrows absent or weak, short, and transverse. Glabella with four pairs of exsagittal tubercles arrayed in rows that parallel tapering margins of glabella. Glabellar length approximately 60 percent length (sagittal) of cranidium. Occipital ring with two pairs of exsagittal tubercles identical to those on glabella. Occipital furrow straight and distinct.

Preglabellar field slightly concave and short, approximately 25 percent glabellar length (sagittal). Anterior border furrow broad, shallow and curved posteriorly near midline. Anterior border prominent, convex, and with many tubercles. Palpebral area of fixigena narrow, approximately 20 percent of maximum (posterior) glabellar width, and steeply upsloping from axial furrow. Palpebral lobes and eyes prominently elevated above cranidium. Anterior fixigena concave; posterior fixigena wide (exsagittal). Posterior sections of facial sutures nearly straight, gonatoparian. Genal angle obtuse, broad. Anterior sections of facial sutures nearly parallel with sagittal line and intersecting margin at nearly right angles.

Librigena convex, strongly upsloping against cranidium; elongate with prominent, elevated eye stalk.

Thorax with 23 segments, initially expanding slightly behind cephalon to achieve maximum transverse width at approximately segment five then gently tapering posteriorly. Axial and pleural lobes convex and arched transversely. Axial lobe well defined by deep axial furrow. Axial rings each with four small tubercles, arrayed in rows (exsagittal) along entire thorax length. Pleural lobes approximately 1.4 times wider (transverse) than axial lobe. Pleurae with tubercles; one prominent tubercle near the downward flexure on each pleuron forms exsagittal row along pleural lobe. Pleural furrows straight and prominent proximally, extending approximately 60 percent of pleural length (transverse). Distal pleurae rounded, reflexed forward with dorsal surface forming articulating facet.

Micropygous; pygidium less than one-half cranidial length (sagittal); typically tucked beneath the thorax and not visible in articulated specimens.

Occurrence.—Moderately common in the upper Weeks, approximately 200 m above the base of the unit. Known also from the overlying Big Horse Limestone Member of the Orr Formation (Eby, 1981), the *Cedaria* zone in the Pilgrim Formation of Montana (Lochman and Duncan, 1944), from the *Cedaria* or *Crepicephalus* zone in the Gaspé

Penninsula, Quebec (Rasetti, 1946), and the Rabbitkettle Formation in the Mackenzie Mountains of Canada (Pratt, 1992).

Discussion.—This trilobite is frequently very difficult to see on fresh bedding surfaces in the Weeks and often only the elevated eyes can be seen projecting above the silt-draped lime mudstone surface. It is generally quite small, the average size being approximately five millimeters, but specimens over 12mm have been recovered. The degree of pustulation varies in Weeks specimens.

Pratt (1992) commented on the confusion that has existed between *Densonella* Shaw, 1952 and *Menomonia*. I concur with Pratt's (1992) suggestion that the genus *Densonella* be considered a junior synonym of *Menomonia*. Assignments under these two generic names present a continuum in character states. Strictly intermediate forms have also been described, as in *Menomonia intermedia* Palmer et al. 1981. Usage has not been consistent and the entire genus is in need of revision. Principal variations include degree of granulation and pustulation over the entire dorsal surface, elevation of eye-stalks, size and shape of glabella, and possibly shape and pustulation on thorax.

Nephalicephalus new genus

Type species.—*Nephalicephalus beebei* new species by monotypy.

Diagnosis.— Cephalon semi-circular, smooth, very modestly and uniformly convex, lacking well-defined axial and border furrows; cephalon border narrow and indistinct. Glabella indistinct, strongly tapering forward to subtriangular. Preglabellar field planar to slightly convex, smooth. Palpebral area of fixigena narrow, slightly upsloping to small palpebral lobes. Eyes small, located at anterior end of glabella, not elevated. Facial sutures gonatoparian; genal angle obtuse, rounded. Anterior sections of facial sutures nearly straight, slightly divergent; posterior sections straight, nearly transverse. Librigena subrectangular, small elevation at eye. Thorax tapering posteriorly, approximately 32 segments. Pygidium minute.

Etymology.—After the Greek *nephali*, sober, and *cephalus*, head; in reference to the subdued cranidial features of the genus.

NEPHALICEPHALUS BEEBEI new species

Figure 2.4.6-4.8

Millardia semele WALCOTT, 1916a, (part), p. 166, pl. 28, fig. 3c, c' (only, 3-3b = *M. semele*).

Diagnosis.— Same as genus.

Description.—Cephalon semicircular with subdued features. Cranidium smooth, gently convex to planar transversely and sagittally. Glabella strongly tapered forward, subtriangular to rounded anteriorly. Axial furrows very shallow, indistinct on most specimens, highlighted by darkened calcite. Short lateral glabellar furrows evident on some specimens but obsolete on most. Occipital furrow shallow and indistinct. Occipital ring narrow (sagittal), indistinct. Preglabellar field narrow, approximately 30 percent glabellar length (sagittal), slightly concave to planar. Cephalon border indistinct on most specimens, exaggerated on compressed specimens. Palpebral area of fixigena narrow, approximately 20 percent basal glabellar width (transverse), slightly up-sloped from axial furrow. Palpebral lobes small, approximately 20 percent glabellar length (sagittal), positioned near anterior end of glabella. Posterior area of fixigena broad (exsagittal), as long as glabella (sagittal). Posterior border furrow indistinct and shallow, posterior border slightly convex. Posterior sections of facial sutures straight, gonatoparian. Genal angle gently curved, obtuse. Anterior sections of facial sutures parallel to slightly divergent, intersecting anterior margin at near right angles.

Librigena broad, nearly planar to gently convex, sub-rectangular. Border furrows and border indistinct.

Thorax long, tapering; variable number of segments up to approximately 32. Posterior segments becoming very small sagitally and transversely. Axial lobe tapering

posteriorly, convex, well demarked by deep axial furrows. Anterior pleurae slightly narrower (transverse) than axial lobe, becoming slightly wider than axial lobe posteriorly. Pleurae bisected by shallow, indistinct pleural furrows extending straight from axial furrow to approximately one-half transverse distance of pleurae. Distal pleurae terminations rounded, reflexed forward with dorsal surface forming articulating facet..

Pygidium minute; absent or tucked beneath thorax and not visible on most specimens. Consists of two or three very narrow axial rings.

Etymology.— After Matthew A. Beebe.

Types.— Holotype FMNH PE57122. Paratypes FMNH PE57121, PE57123.

Measurements.— Holotype; total body length (sagittal) 7.8 mm. Maximum cranidium width 5.2 mm (transverse). Cranidium length (sagittal) 2 mm.

Occurrence.—This taxon is relatively common in the upper Weeks Formation.

Discussion.—The cranidial characters of this taxon are very indistinct, giving a smooth, shield-like appearance to the cephalon. Specimens achieve lengths of up to two centimeters. Preservation is variable, but there are significant morphological variations. Notably, Figure 2.4.8 shows a moderately sized teratological specimen with three abnormally large thoracic segments (segments 7-9). Specimens of this species are easily confused with *M. semele* from the Weeks Formation because of overall similarity in size and shape and the presence of a relatively large number of thoracic segments with very similar pleural termini.

Family Marjumiidae Kobayashi, 1935

Genus Modocia Walcott, 1924

Type species.—*Arionellis oweni* Meek and Hayden, 1861, p. 436.

Discussion.—Palmer (1954) provides the concept of *Modocia* followed here.

Modocia weeksensis new species

Figure 2.4.11-4.13

Weeksina sp. Robison, 1960, p. 18, pl. 1, fig. 23.

Diagnosis.— Member of *Modocia* with palpebral area of fixigena relatively narrow, approximately 20 percent of posterior glabellar width (transverse). Anterior sections of facial sutures straight to slightly divergent, bending medially near border. Thorax with 12 segments.

Description.—Cranidium smooth, convex sagittally and transversely. Glabella tapered forward, anteriorly rounded, approximately 65 percent length (sagittal) of cranidium. Three pairs of variably developed, inward-backward curved lateral glabellar furrows not reaching axial furrows. Axial furrows narrow and distinct, preglabellar furrow less so. Occipital furrow straight (transverse), broadest and deepest exsagittally. Occipital ring prominent, with small, indistinct medial tubercle; posteriorly convex. Preglabellar field short (sagittal), less than 20 percent glabellar length; flat to slightly concave. Anterior border furrow straight (transverse), shallow, broad and distinct. Anterior border gently convex, of unequal length (sagittal), with maximum length medially; greater than or equal to preglabellar field length. Palpebral lobes semicircular, approximately 35 percent glabellar length (sagittal), located near glabellar midpoint. Palpebral area of fixigena slightly upsloping from axial furrow, narrow, approximately 20 percent of maximum (posterior) glabellar width (transverse). Posterior area of fixigena narrow and of nearly uniform length (sagittal) laterally. Posterior sections of facial sutures opisthoparian, forming nearly straight line between eye and posterior border furrow; geniculate at border and intersecting posterior margin at near right angle. Anterior sections of facial sutures nearly straight (exsagittal) to slightly divergent; intersect margin at nearly right angles along exsagittal line between margin and lateral margins of occipital ring.

Librigena roughly triangular with short, flattened genal spine, which extends to approximately third segment.

Thorax with 12 segments. Axial lobe finely and sparsely granular, slightly tapered, transverse width approximately 80 percent pleural lobe; small medial tubercle identical to that on occipital lobe present on axial rings but not always apparent on worn or poorly prepared specimens. Thorax of approximately equal width (transverse) from cranidium to segment 10. Pleurae bisected by straight, broad, distinct pleural furrow extending approximately 75 percent pleural width (transverse) anteriorly, and almost entire pleural width posteriorly. Pleural tips slightly pointed and curved posteriorly.

Micropygous; pygidial sagittal length approximately 50 percent cranidial length. Axial lobe extending nearly to margin, tapering; four axial rings becoming less distinct posteriorly. Pleural field slightly convex, with four or more shallow, backwards curved pleural furrows extending to near border furrow and becoming obsolete posteriorly. Border moderately broad, flat, and of constant width. Border furrow indistinct. Posterior pygidial margin with indentation at midline.

Etymology.— After the Weeks Formation, where it occurs in large numbers.

Types.— Holotype FMNH PE57125. Paratypes FMNH PE57124, PE57126.

Measurements.— Holotype; total body length (sagittal) 15.0 mm; maximum body width 8.0 mm (transverse); cranidial length (sagittal) 5.5 mm; pygidial length (sagittal) 2.0 mm.

Occurrence.— *M. weeksensis* is the second most abundant trilobite in the upper Weeks Formation.

Discussion.— Articulated exuvia lacking free cheeks are the most commonly encountered remains; wholly articulated individuals preserving librigena and ventral sternites are comparatively rare. Specimens in the Upper Weeks Formation achieve lengths of up to three centimeters.

Family Norwoodiidae Walcott, 1916

Genus Norwoodia Walcott, 1916

Type species.—*Norwoodia gracilis* Walcott, 1916a, p. 168, pl. 27.

Discussion.— Pratt (1992) provide the concept of *Norwoodia* followed here.

Norwoodia bellaspina new species

Figure 2.4.10

Diagnosis.— Glabella less than one-half cranidial length (sagittal); two pairs of weak to obsolete lateral glabellar furrows. Occipital furrow effaced; occipital ring with robust spine extending to near base of thorax. Palpebral area of fixigena broad, approximately 60 percent basal glabellar width (transverse). Cephalic border furrow very broad, of constant width anteriorly, widening posteriorly. Anterior facial sutures slightly divergent. Fourth thoracic segment bears long, slender spine greater than length of body.

Description.— Cephalon large, one-half body length (sagittal), semicircular; posterior cephalic width (transverse) slightly greater than body length (sagittal). Cranidium gently convex sagittally and transversely. Glabella small, approximately 45 percent cranidial length (sagittal), slightly tapered forward, rounded anteriorly; two pairs of weak, transverse, lateral glabellar furrows. Axial furrows narrow and distinct, preglabellar furrow less so. Occipital furrow effaced. Occipital ring with long, relatively robust, slightly flattened spine extending to anterior margin of pygidium; base of spine expanded to cover entire transverse width of occipital ring. Preglabellar field long, approximately one-half sagittal length of glabella. Anterior border furrow wide, 35 percent glabellar length (sagittal), flat, shallow. Anterior border slightly upturned and broad, approximately one-quarter glabellar length (sagittal). Palpebral lobes small, approximately 22 percent glabellar length (sagittal), positioned anterior of glabellar midlength. Palpebral area of fixigena approximately 60 percent of posterior glabellar width (transverse). Posterior border furrow of fixigena prominent, slightly broader

(transverse) than posterior glabellar width. Posterior border of fixigena extends into a moderately wide, flattened, inward-curved genal spine extending nearly to pygidium. Posterior facial section of facial sutures proparian, anteriorly curved medially but intersecting margin just posterior of eyes with slightly posterior orientation. Anterior sections of facial sutures slightly divergent anterior of eyes, curved to become parallel to slightly convergent near anterior border furrow.

Librigena nearly triangular, slightly convex.

Thorax tapered posteriorly, with nine segments; sagittal length approximately 70 percent that of cranidium. Lateral margin of thorax is continuous with inner outline formed by broad border furrow of cephalon; thoracic width (transverse) approximately 58 percent posterior cephalic width, leaving wide space between genal spines and thorax. Axial lobe slightly convex, tapering, width (transverse) approximately 68 percent pleural lobe. Fourth axial ring bears long, slender, rounded spine extending well beyond pygidium; length of spine approximately 1.1 times total body length, situated directly below occipital spine. Pleural lobes planar to very slightly convex. Pleurae with pleural furrows that extend to near pleurae termini. Anterior pleurae terminate in short, triangular spines; posterior pleurae terminations blunt, rounded.

Pygidium micropygous, approximately one-quarter glabellar length (sagittal), with two axial rings and weak interpleural furrow not extending to narrow border. Pygidium not well preserved on illustrated holotype.

Etymology.— Name originally proposed by Beebe (1990). From the Latin *bella*, meaning beautiful, and *spina*, meaning thorn; in reference to long and slender axial spine.

Types.— Holotype USNM 437971.

Measurements.— Holotype total body length (sagittal), including long thoracic spine 16 mm. Body length excluding spine 8.7 mm (sagittal). Maximum cranidium width 11.5 mm (transverse). Cranidium length (sagittal) 4 mm.

Occurrence.—Known only from the upper Weeks Formation where it is rare.

Discussion.—This taxon is rare in the upper Weeks and is quite small; most specimens are less than 6 mm excluding axial spine. *N. bellaspina* differs from *N. occidentalis* (Lochman *in* Lochman and Duncan, 1944) primarily by having an anterior border furrow that is of nearly equal breadth in the anterior half of the cephalon and by somewhat narrower fixed cheeks. It is unknown whether *N. occidentalis* had a thoracic axial spine.

Family Llanoaspididae Lochman *in* Lochman and Duncan, 1944

Genus Genevievella Lochman, 1936

Type species.—*Genevievella neunia* Lochman, 1936, p. 41, pl. 9, figs. 12-21.

Discussion.—Pratt (1992) provides the concept of *Genevievella* followed here.

Genevievella granulatus (Walcott, 1916)

Figure 2.5.1-5.3

Asaphiscus? granulatus Walcott, 1916b, p. 385, pl. 61.

Weeksina granulata (Walcott) Resser, 1935, p. 46.

Diagnosis.— Glabella granular, large, convex, slightly tapering forward and extending to anterior border furrow. Occipital ring large, granular, expanded, strongly posteriorly convex. Palpebral lobes small, less than 25 percent of glabellar length (sagittal), located posterior of glabellar midlength. Palpebral area of fixigena broad, approximately 40 percent basal glabellar width (transverse). Anterior facial sutures slightly divergent. Anterior cephalon margin rounded. Thorax with 10 segments; ninth axial ring with rounded slender spine extending beyond pygidium.

Description.— Cranidium strongly convex sagittally and transversely. Glabella granular, large, convex, slightly tapering forward, lateral glabellar furrows short, weak to obsolete; glabella nearly as broad (transverse) as long (sagittal), extends to anterior border furrow, well defined by moderately deep axial furrows. Occipital furrow rather broad, distinct, gently curved posteriorly near midline. Occipital lobe prominent, broad, approximately

40 percent glabellar length (sagittal), coarsely granular, posteriorly convex; occipital lobe extends transversely through axial furrows, abruptly deflecting axial furrows laterally along its length. Palpebral area of fixigena slightly convex transversely and sagittally, broad, approximately 43 percent of maximum glabellar width (transverse). Eye ridges present, broad, indistinct. Palpebral lobes small, approximately 25 percent glabellar length (sagittal), slightly upturned, located near posterior margin of glabella. Posterior fixigena angled posteriorly. Posterior border furrow of fixigena broad, prominent; posterior border convex, broad, prominent. Anterior border less distinct, less broad, well-defined by moderately deep and more narrow border furrow. Posterior facial sutures curved, crossing lateral border furrow anterior of genal angle; gonatoparian. Anterior facial sutures weakly divergent just anterior of eyes, becoming nearly parallel to convergent and intersecting margin approximately along exsagittal line with eyes.

Librigena convex, strongly upsloped from lateral margin to semi-circular, small eye. Genal spines straight to slightly inward-curved, broad, robust, extending to approximately sixth thoracic segment or 65 percent cranidial length (sagittal).

Thorax with 10 segments, ninth axial ring bearing robust, rounded spine nearly the length (sagittal) of cranidium, extending just beyond pygidium; scattered, small pustules occur on all protions of thorax. Pleural lobes approximately 1.3 times wider than axial lobe. Pleurae with well defined pleural furrow extending laterally approximately two-thirds length (transverse) of pleurae; pleurae terminating in short, broad, flattened, straight to slightly posteriorly reflexed spines that become more strongly posteriorly curved towards pygidium.

Pygidium approximately 65 percent length (sagittal) of cranidium; elliptical in outline with at least five moderately distinct and posteriorly curved pleural furrows. Axial ring convex, prominent, rounded posteriorly, terminating approximately 60 percent length (sagittal) of pygidium, leaving broad, flat to slightly convex posterior border.

Pleural field smooth, gently convex. Margin of pygidium smooth, narrow, slightly upturned. Border furrow broad, shallow, indistinct.

Occurrence.—Moderately common in the upper Weeks Formation (Marjuman).

Discussion.—*G. granulatus* is one of the more robust trilobite taxa in the Weeks Formation and achieves lengths of up to two centimeters. In this regard, *G. granulatus* from the Weeks Formation is unusual in comparison to other occurrences of the genus, which are primarily rather small trilobites. Completely articulated specimens are relatively rare in the Weeks and most specimens with any articulation are found lacking pygidia. This trilobite is also occasionally found enrolled.

Family Tricrepicephalidae Palmer, 1954

Genus Tricrepicephalus Kobayashi, 1935

Type species.—*Arionellus texanus* Schumard, 1861, p. 218.

Discussion.— Palmer (1954) provides the concept of *Tricrepicephalus* followed here.

Tricrepicephalus texanus (Shumard, 1861)

Figure 2.5.4-5.7

Tricrepicephalus coria Palmer, 1954, p. (see for synonymy to 1954); Stitt, 1998, p. 1024, fig. 7.27; Stitt and Perfetta, 2000, p. 212, figs. 9.20-9.27.

Tricrepicephalus texanus Palmer, 1954, p. 755, pl. 81, figs. 1-4, 6 (see for synonymy to 1954); Pratt, 1992, p. 62, pl. 21, figs. 1-7 (see for synonymy to date).

Description.—Cranidium very convex transversely and sagittally, bearing many evenly and rather widely scattered, fine granules over entire surface. Axial and preglabellar furrows well defined, moderately broad, deep. Glabella distinct, tapered forward, rounded anteriorly; lateral glabellar furrows obsolete. Occipital furrow distinct, moderately broad, abaxial sections slightly anteriorly deflected. Occipital ring posteriorly convex, modestly longer (sagittal) than thoracic segments, approximately same length

(sagittal) as preglabellar field. Preglabellar field convex, approximately 16 percent glabellar length (sagittal). Anterior border furrow distinct, moderately broad, with three transversely elongate pits. Anterior border arched, broadest medially, slightly convex to flat; maximum anterior border length (sagittal) approximately 24 percent glabellar length. Palpebral area of fixigena modestly upsloping from axial furrows, approximately 30 percent (transverse) posterior glabellar width; eye ridges obsolete. Palpebral furrows rather broad, distinct anterior and posterior of eye midpoint (exsaggital), nearly obsolete at eye midpoint. Palpebral lobes distinct, slightly upsloped from palpebral furrows, approximately 38 percent glabellar length (sagittal), located just posterior of glabellar midlength. Fixigena posterior border furrow moderately deep, broad, distinct, transverse. Posterior limb of fixigena convex, upward sloped to posterior section of facial suture and palpebral area. Posterior border convex, distinct, slightly expanded (exsagittal) abaxially. Facial sutures opisthoparian; anterior sections slightly divergent, straight anterior of eye, sharply convergent at anterior border, intersecting anterior margin at very shallow angle which defines anterior border arch. Posterior sections of facial sutures nearly straight, slightly posteriorly deflected, nearly intersect junction of posterior and lateral border furrows.

Librigena bear many small, widely scattered, fine granules like cranidium. Lateral border furrow broad, very slightly convex, expanding slightly posteriorly. Lateral border broad, rather shallow, extending posteriorly into tapered, moderately rounded genal spine extending to approximately fifth thoracic segment; anterior portion of border extends into sharply tapered and pointed tip defined by suture line. Librigenal field slightly convex, strongly upsloped from border furrow to suture. Eye prominent, forming semicircular and vertically oriented ridge.

Thorax with 13 segments. All portions of thorax bear many small, widely scattered, fine granules that are somewhat less distinct than those on cranidium and librigena. Axial lobe distinct, slightly tapering posteriorly, defined by moderately deep and moderately

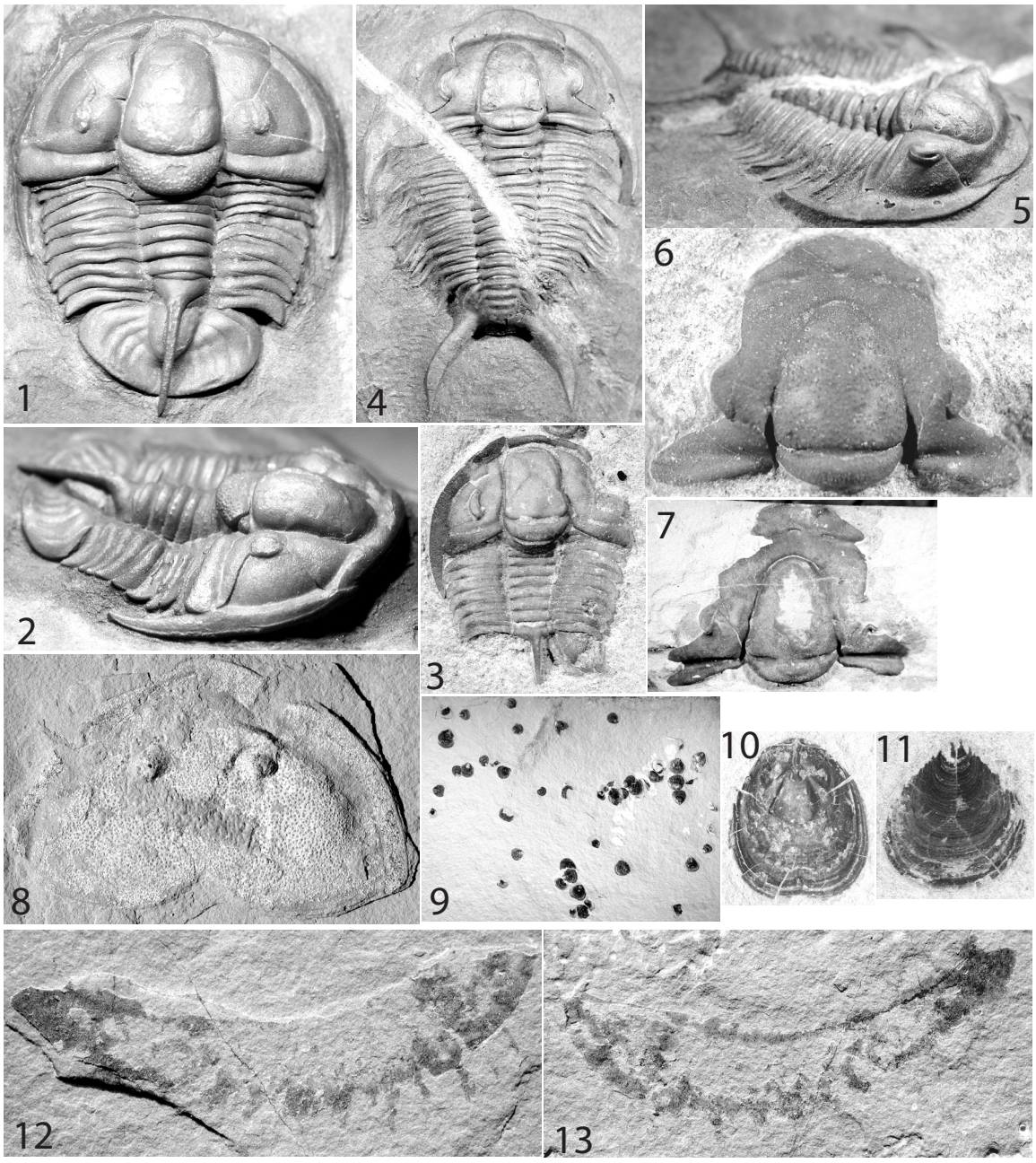
broad axial furrows; transversely convex. Pleurae transversely convex, slightly wider (transverse) than axial lobe. Pleurae bisected by straight, very distinct, deep, broad, pleural furrows not reaching pleural tips; furrows taper abruptly abaxially to sharp points where pleurae begin to taper into long, somewhat rounded, posteriorly deflected, sharp spines; length of pleural spines approximately 60 percent width (transverse) of axial lobe.

Pygidium sagittaly and transversely convex; micropygous, with two posterio-laterally directed, slightly inwardly curved, robust, rounded pygidial spines; spines extend approximately 65 percent the length (sagittal) of cranidium beyond pygidial margin. Granules or pustules not evident on available specimen; if granules are present, they must be less developed than those on thorax and cranidium. Excluding spines, pygidial length (sagittal) approximately 89 percent glabellar length. Axial lobe broad, strongly convex, distinct, approximately 48 percent total pygidial width (transverse); three prominent axial rings and one very subdued ring posteriorly. Axial lobe tapers only slightly, extends approximately 81 percent pygidial length (sagittal). Border and border furrow indistinct. Pleural field convex, upsloped from margin to axial lobe, at least three pleural furrows; anterior furrow broad and distinct, posterior furrows becoming less distinct then obsolete.

Occurrence.—Relatively uncommon in the upper Weeks Formation (Marjuman) but widespread in North America in the *Cedaria* and *Crepicephalus* zones.

Discussion.— Palmer (1954) noted much variability in the degree of tuberculation and the length of the anterior border in *Tricrepicephalus* and recognized only three species, the pustulous *T. coria* (Walcott, 1916), the evenly granular *T. texanus* (Shumard, 1861), with a mostly smooth glabella, and *T. tripunctatus* (Whitfield, 1876), which bears an axial spine. Based on a large number of specimens collected from the Rabbitkettle Formation, Pratt (1992) suggested that two of these species, *T. coria* and *T. texanus,* are synonyms that reflect end members of a continuous distribution in pustule and granule density. Here, I follow Pratt's (1992) synonymy and accordingly designate the Weeks specimens as *T. texanus*. Based on Palmer's (1954) criteria, these specimens would be referred to

Figure 2.5: 1-3, *Genevievella granulatus* (Walcott) (USNM 437962); 1, dorsal view of articulated exoskeleton, X3.2; 2, right-lateral view of dorsal exoskeleton shown in 5.1, X2.8; 3, dorsal view of semi-articulated specimen, (FMNH PE57127), X5.8; 4-7, *Tricrepicephalus texanus* (Shumard); 4, dorsal view of articulated exoskeleton, partially distorted by calcite-filled fracture running diagonally from lower right to upper left of specimen, (USNM 437945), X1.7; 5, right-lateral view of dorsal exoskeleton shown in 5.4, X1.8; 6, dorsal view of isolated cranidium (FMNH PE), X3.9; 7, dorsal view of isolated cranidium (FMNH PE), X1.3; 8, *Beckwithia typa* Resser (FMNH PE57128), dorsal view of head shield, X1.2; 9-11, *Lingulella sp*; 9, bedding plane view of multiple valves, (FMNH PE), X0.5; 10, detail of interval valve surface, (FMNH PE57129), X3.6,; 11, detail of internal valve surface, (FMNH PE57130), X4.1; 12-13, unidentified soft-bodied or lightly scleritized organism, specimens are part and counter-part of same individual; 12, (FMNH PE57131), X2.3; 13, (FMNH PE57132), X2.3.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T. coria. However, none of the Weeks specimens are tuberculate to the degree of the specimens illustrated by Pratt (1992) and Palmer (1954). In fact, the dorsal exoskeleton of the Weeks specimens is essentially smooth with very fine and even granulation over the cranidium, thorax, and possibly the pygidium. Based on specimens in the collections of amateur enthusiasts, there is morphological variation in Weeks Formation *Tricrepicephalus* beyond that documented here. *Tricrepicephalus* specimens achieve very large sizes in the upper Weeks. Pygidia more than 6 cm in length (including spines) have been found.

Family uncertain

Genus SELENOCORYPHE new genus

Type species.—*Selenocoryphe platyura* new species by monotypy.

Diagnosis.— Body wide, maximum transverse width approximately 85 percent sagittal body length. Macropygous. Cephalon crescentric. Glabella large, slightly tapered anteriorly, reaches into and interrupts narrow, distinct anterior border furrow; glabellar furrows obsolete. Anterior border approximately 16 percent glabellar length (sagittal), convex. Palpebral lobes semi-circular, moderately long, approximately 30 percent glabellar length (sagittal), located posterior of glabellar midpoint. Posterior area of fixigena narrow (exsagittal), angled slightly posteriorly; posterior border furrow narrow, distinct. Anterior facial sutures slightly divergent, curved inward at border; farthest abaxial point of anterior facial suture occurs within border. Librigena slightly convex; lateral border of librigena wide, expanding posteriorly, reaching approximately 84 percent of transverse width of librigenal field. Genal spines short, broad and flattened. Thorax with 10 segments; pleurae with straight furrows extending approximately 60 percent of transverse pleural width, terminating in anterior portion. Pygidium large, subovate, as long as or slightly longer than cranidium. Pygidium with eight axial rings, border very broad, smooth.

Etymology.—Name originally proposed by Beebe (1990). After the Greek *selene*, meaning moon, and *koryphe*, meaning head; in reference to the crescentric cephalon of this trilobite.

SELENOCORYPHE PLATYURA new species

Figure 2.4.9

Diagnosis.— Same as genus.

Description.—Cephalon cresentric, width (transverse) approximately 40 percent length (sagittal). Glabella large, extends onto and interrupts anterior border furrow, slightly tapered forward, rounded anteriorly. Basal glabellar width (transverse) only slightly less than glabellar sagittal length. Three pairs of lateral glabellar furrows inward-backward curved, indistinct on most specimens. Occipital furrow narrow, distinct, transverse. Occipital ring only slightly convex posteriorly. Axial furrows narrow, distinct. Anterior border furrow moderately deep, narrow. Anterior border narrow. Palpebral lobes approximately 30 percent sagittal glabellar length, located slightly posterior of glabellar midlength, strongly curved. Palpebral area of fixigena moderately convex, approximately 25 percent of basal glabellar width (transverse). Posterior fixigena posteriorly deflected, narrow (exsagittal), approximately 25 percent glabellar length (sagittal). Posterior border furrow, narrow, distinct, not parallel to posterior border which expands exsagittally. Posterior sections of facial sutures gently curved, intersecting posterior margin well inside genal angle. Anterior facial sutures slightly divergent anterior of eyes, curved anteriorly, becoming convergent near anterior border furrow.

Librigena distinctive, large, lateral border broad anteriorly, expanding posteriorly. Posterior border extends into short, flattened, broad genal spine extending to about fifth thoracic segment. Eye forms short, vertical, strongly curved semicircular ridge; deep, circular notch formed by eye.

Thorax with 10 segments; widest at midlength, near termination of genal spines. Axial lobe convex, slightly tapered (less than 20 percent) posteriorly, approximately 90 percent width (transverse) of pleural lobe. Pleural lobes moderately convex. Pleural furrows straight, extending from near axial furrow to anterior margin of pleurae, approximately 60 percent of distance to pleural terminations. Pleurae tips backward curved, slightly pointed and extended to very short spines.

Pygidium subovate, as large or slightly larger than length (sagittal) of cranidium. Axial lobe rounded and tapered posteriorly; extending approximately 68 percent of pygidium length (sagittal) and 25 percent maximum pygidial width (transverse). Eight axial rings and terminal piece present on axial lobe. Pleural furrows indistinct, extending from axial furrows to border furrow. Pleural field terminates slightly anterior of axial lobe termination. Border furrow shallow. Pygidial border very broad, approximately 40 percent pygidial length (exsagittal), broadest posteriorly, smooth. Sagittal line of border with narrow ridge extending from axial lobe to approximately half the distance to posterior margin.

Etymology.— Name originally proposed by Beebe (1990). From the Greek *platys*, meaning broad, and *oura*, tail

Types.— Holotype USNM 437980.

Measurements.— Holotype; total body length (sagittal) 34.5 mm. Maximum cranidium width 29.5 mm (transverse). Cranidium length (sagittal) 9.5 mm. Pygidium length (sagittal) 13.0 mm.

Occurrence.—Known only from the upper Weeks Formation (Marjuman) in North Canyon where it is rare.

Discussion.—This taxon is unlike any other known trilobite from the Marjuman. The wide aspect of this trilobite, large pygidium, and distinctive cranidium and librigena of this trilobite are the distinguishing characteristics. Commonly, *S. platyura* is preserved in a slightly dorsal-ventrally flattened state. Fully three-dimensional, uncompressed

specimens are occasionally recovered and the foregoing description is applicable to these specimens as well.

Order Aglaspidida Raasch, 1939

Family Aglaspididae Miller, 1877

Genus Beckwithia Resser, 1931

Type species.—*Beckwithia typa* Resser, 1931, p. 1-5, pl. 1, figs. 1-3.

Discussion.— Hesselbo (1989) provides the concept of *Beckwithia* followed here.

Beckwithia typa Resser, 1931

Figure 2.5.8

Beckwithia typa Resser, 1931, p. 1-5, pl. 1, figs. 1-3; Raasch, 1939, p. 46-47, p. 138-139, pl. 19; Størmer, 1944, p. 75, figs. 14; Størmer, 1955, fig. 9.1; Caster and Brooks, 1956, p. 175, fig. B5; Raw, 1957, p. 175-176; Chlupác, 1965, p. 33; Chlupác and Havlíchek, 1965, p. 16; Repina and Okuneva, 1969, p. 103; Bergström, 1979, p. 37, fig. 1.17; Hesselbo, 1989, p. 637, figs. 1-2.

Discussion.—Completely articulated individuals of this rare arthropod have been recovered from the Weeks Formation at the study site. The most common elements, however, are the head shields, which appear to be at least weakly pyritized.

Order Lingulida Waagen, 1885

Family Obolidae King, 1846

Genus Lingulella Salter, 1866

Type Species.—By subsequent designation of Dall, 1870, p. 159; *Lingula davisii* M'Coy, 1851.

Discussion.—Sutton et al. (2000) provide the concept of *Lingulella* followed here.

LINGULELLA species undetermined

Figure 2.5.9-5.11

Discussion.—Individuals of this genus are very well preserved in the Weeks Formation, with detailed internal morphology visible on many specimens. Large numbers of well-preserved specimens occur on single bedding surfaces (Figure 2.5.9), making this assemblage ideal for the quantitative study of variation within populations of a relatively understudied but ubiquitous Cambrian genus.

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2.7 References

Babcock, L. A. 1993. Trilobite malformations and the fossil record of behavioral asymmetry. Journal of Paleontology, 67:217-229.

Beebe, M. A. 1990. Trilobite faunas and depositional environments of the Weeks Formation (Cambrian), Utah. Unpublished Ph.D. dissertation, University of Kansas, Lawrence, 102 p.

Bergstöm, J. 1979. Morphology of fossil arthropods as a guide to phylogenetic relationships, p. 3-56. *In*, A. P. Gupta (ed.), Arthropod Phylogeny. Van Nostrand Reinhold, New York.

Briggs, D. E. G. and R. A. Robison. 1984. Exceptionally preserved nontrilobite arthropods and *Anomalocaris* from the Middle Cambrian of Utah. University of Kansas Paleontological Contributions, 111:1-24.

Bently, C. B. 1958. Upper Cambrian stratigraphy of western Utah. Brigham Young University Research Studies Geology Series, 5(6), 70 p.

Caster, K. E. and H. K. Brooks. 1956. New fossils from the Canadian-Chazyan (Ordovician) hiatus in Tennessee. Bulletin of American Palaeontology, 36:157-199.

Conway-Morris, S. and D. A. Robison. 1988. More soft-bodied animals and algae from the Middle Cambrian of Utah and British Columbia. University of Kansas Paleontological Contributions, 122:23-48.

Chlupác, I. 1965. Xiphosuran merostomes from the Ordovician of Bohemia. Sborník Geologickych ved paleontologie, rada, P5:7-38.

Chlupác, I. and V. Havlíchek. 1965. *Kordymirus* n.g., an new aglaspid merostome of the Cambrian of Bohemia. Sborník Geologickych ved paleontologie, rada, P6:7-20.

Dall, W. H. 1870. A revision of the Terebratulidae and Lingulidae. American Journal of Conchology, 6:88-168.

Deiss, C. 1938. Cambrian formations and sections in part of the Cordilleran trough. Geological Society of America Bulletin, 49:1067-1168.

Droser, M. L. and X. Li. 2001. The Cambrian radiation and the diversification of sedimentary fabrics, p. 127-169. *In* A. Y. Zhuravlev and R. Riding (eds.), The ecology of the Cambrian radiation. Columbia University, New York.

Droser, M. L. and D. J. Bottjer. 1993. Trends and patterns of Phanerozoic ichnofabrics. Annual Review of Earth and Planetary Sciences, 21:205-225.

Eby, R. G. 1981. Early Late Cambrian trilobite faunas of the Big Horse Limestone and correlative units in central Utah and Nevada. Unpublished Ph. D. dissertation, State University of New York, Stony Brook, 613 p.

Fortey, R. A. 1990. Ontogeny, hypostome attachment and trilobite classification. Palaeontology, 33:529-576.

Hesselbo, S. P. 1989. The aglaspid artropod *Beckwithia* from the Cambrian of Utah and Wisconsin. Journal of Paleontology, 63:636-642.

Janussen, M. Steiner, and Z. Maoyan. 2002. New well-preserved scleritomes of Chancelloridae from the Early Cambrian Yuanshan Formation (Chengjiang, China) and the Middle Cambrian Wheeler Shale (Utah, USA) and paleobiological implications. Journal of Paleontology 76:596-606.

Kidwell, S. M. and W. J. Bosence. 1991. Taphonomy and time-averaging of marine shelly faunas, p. 115-209. *In* P. A. Allison and D. E. G. Briggs (eds.), Taphonomy, releasing the data locked in the fossil record. Plenum Press, New York.

Kobayashi, T. 1935. The Cambro-Ordovician formations and faunas of South China. Palaeontology. Part III. Cambrian faunas of South China with a special study on the Cambrian trilobites genera and families. Journal of the Faculty of Sciences, Tokyo University, 15:151-192.

Lochman, C. 1936. New trilobite genera from the Bonneterre Dolomite (Upper Cambrian) of Missouri. Journal of Paleontology, 10:35-43.

-----. 1938a. Middle and Upper Cambrian faunas from western Newfoundland. Journal of Paleontology, 12:461-477.

-----. 1938b. Upper Cambrian faunas of the Cap Mountain Formation of Texas. Journal of Paleontology, 12:72-85.

-----. 1940. Fauna of the basal Bonneterre dolomite (Upper Cambrian) of southeastern Missouri. Journal of Paleontology, 14:1-53.

-----. 1950. Upper Cambrian faunas of the Little Rocky Mountains. Journal of Paleontology, 24:322-353.

Lochman, C., and D. Duncan. 1944. Early Upper Cambrian faunas of central Montana. Geological Society of America Special Paper, 54, 181 p.

M'coy, F. 1851. On some new Cambro-Silurian fossils. Annals and Magazine of Natural History, 2nd series, 8:387-409.

Meek, F. G., and F. V. Hayden. 1861. Descriptions of new lower Silurian (Primordial), Jurassic, Cretaceous and Tertiary fossils collected in Nebraska Territory. Proceedings of the National Academy of Science, Philadelphia, 5:415-447.

Palmer, A. R. 1954. The faunas of the Riley Formation in central Texas. Journal of Paleontology, 28:709-786.

-----. 1962. *Glyptagnostus* and associated trilobites in the United States. U. S. Geological Survey Professional Paper 374F, 49 p.

-----. 1984. The biomere problem: evolution of an idea. Journal of Paleontology, 58:599-611.

Palmer, A. R., J. W. Cowie, and R. G. Eby. 1981. A Late Cambrian (Dresbachian, *Crepicephalus* zone) fauna from the Boothia Penninsula, District of Franklin. Geological Survey of Canada Bulletin, 300:1-6.

Raasch, G. O. 1939. Cambrian merostomata. Geological Society of America Special Paper 16, 146 p.

Rasetti, F. 1946. Early Upper Cambrian trilobites from western Gaspé. Journal of Paleontology, 20:442-462.

-----. 1965. Upper Cambrian trilobite faunas of northeastern Tennessee. Smithsonian Miscellaneous Collections, 148(3), 127 p.

Raw, F. 1957. Origin of chelicerates. Journal of Paleontology, 31:139-192.

Rees, M. N. 1986. A fault-controlled trough through a carbonate platform: Middle Cambrian House range embayment. Geological Society of America Bulletin, 97: 1054-1069.

Repina, L. N. and O. G. Okuneva. 1969. Cambrian arthropods of the Maritime Territory. Paleontological Journal, 3:95-103.

Resser, C. E. 1931. A new Middle Cambrian merostome crustacean. Proceedings of the United States National Museum, 79(33), 4 p.

-----. 1935. Nomenclature of some Cambrian trilobites. Smithsonian Miscellaneous Collections, 93(5), 46 p.

-----. 1938a. Cambrian system (restricted) of the southern Appalachians. Geological Society of America Special Paper, 15, 140 p.

-----. 1938b. Fourth contribution to nomenclature of Cambrian fossils. Smithsonian Miscellaneous Collections, 97(10), 43 p.

Rigby, J. K. 1978. Porifera of the Middle Cambrian Wheeler Shale, from the Wheeler Amphitheater, House Range, in western Utah. Journal of Paleontology 52(6):1325-1345

Robison, R. A. 1960. Some Dresbachian and Franconian trilobites of western Utah. Brigham Young University Research Studies Geology Series, 7(3), 59 p.

-----. 1987. Superclass Trilobitomorpha, p. 221-241. *In*, R. S. Boardman, A. H. Cheetham, and A. J. Rowell (eds.), Fossil Invertebrates. Blackwell, Palo Alto.

Shaw, A. B. 1952. Paleontology of northwestern Vermont. Journal of Paleontology, 26: 458-483.

Shimer, H. W., and R. R. Shrock. 1944. Index fossils of North America. John Wiley and Sons, New York, 837 p.

Stitt, J. H. 1998. Trilobites from the *Cedarina dakotaensis* Zone, lowermost part of the Deadwood Formation (Marjuman Stage, Upper Cambrian), Black Hills, South Dakota. Journal of Paleontology, 72:1030-1046.

Stitt, J. H. and P. J. Perfetta. 2000. Trilobites, biostratigraphy, and lithostratigraphy of the *Crepicephalus* and *Aphelaspis* zones, lower Deadwood Formation (Marjuman and Steptoean stages, Upper Cambrian), Black Hills, South Dakota. Journal of Paleontology, 74:199-223.

Størmer, L. 1944. On the relationships and phylogeny of fossil and Recent arachnomorpha. Skrifter utgitt av det Norske videnskspsakademi i Oslo. I. Matematisk-naturvidenskabelig klasse, 5:1-158.

-----. 1955. Chelicerata, Merostomata, p. 1-44. *In*, R. C. Moore (ed.), Treatise on Invertebrate Paleontology, Part P, Arthropoda 2. Geological Society of America and University of Kansas Press, Lawrence.

Sutton, M. D., M. G. Bassett, and L. Cherns. 2000. The type species of *Lingulella* (Cambrian Brachiopoda). Journal of Paleontology, 74:426-438.

Tasch, P. 1951. Fauna and paleoecology of the Upper Cambrian Warrior Formation of central Pennsylvania. Journal of Paleontology, 25:275-306.

Walcott, C. D. 1890. Descriptions of new forms of Upper Cambrian fossils. United States National Museum Proceedings, 13:266-279.

-----. 1908a. Cambrian geology and paleontology I, no. 1, Nomenclature of some Cambrian Cordilleran formations. Smithsonian Miscellaneous Collections, 53(1):1-12.

-----. 1908b. Cambrian geology and paleontology I, no. 2, Cambrian trilobites. Smithsonian Miscellaneous Collections, 53(2):13-52.

-----. 1916a. Cambrian geology and paleontology III, no. 3, Cambrian trilobites. Smithsonian Miscellaneous Collections, 64(3):157-258.

-----. 1916b. Cambrian geology and paleontology III, no. 5, Cambrian trilobites. Smithsonian Miscellaneous Collections, 64(5):303-570.

-----. 1924a. Cambrian geology and paleontology V, no. 2, Cambrian and Lower Ozarkian trilobites. Smithsonian Miscellaneous Collections, 75(2):53-60.

Whitfield. 1878. Preliminary descriptions of new species of fossils from the lower geological formations of Wisconsin. Annual Report of the Geological Society of Wisconsin, 1877:59-89.

Whittington, H. B. 1992. Trilobites. Fossils Illustrated 1, 145 p.

-----. 1997. Morphology of the exoskeleton, p. O1-O67. *In* R. L. Kaesler (ed.), Treatise on Invertebrate Paleontology, Part O, Arthropoda 1, Trilobita (revised). Geological Society of America and University of Kansas Press, Lawrence.

Wilson, J. L. 1954. Late Cambrian and Early Ordovician trilobites from the Marathon Uplift, Texas. Journal of Paleontology, 28:249-285.