

An integrated trilobite and conodont biostratigraphy across the base of the Laurentian Whiterockian Series (lower Middle Ordovician) at its stratotype, Whiterock Canyon Narrows, Nevada

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Abstract.—The outcrop at Whiterock Canyon Narrows, Nevada, is the stratotype for the Middle Ordovician Whiterockian Series in Laurentia. Contrasts in the distribution of trilobites and conodonts between two parallel sections at the stratotype demonstrate the presence of an unconformity separating Ibexian faunas (the historic trilobite Zone J, the more recent restricted “*Pseudocybele nasuta*” trilobite Zone, the *Reutterodus andinus* conodont Zone) from overlying Whiterockian faunas (Zone L, the *Psephosthenaspis pseudobathyrurus* trilobite Zone, the *Orthidiella* brachiopod Zone, the *Tripodus combsi* conodont Zone). The unconformity represents the erosional loss of a minimum of 10 m of shale and bedded limestone within the upper Ninemile Formation. In comparison to more continuous section in the Ibex region, Utah, the equivalent to the thin *Psephosthenaspis microspinosa* trilobite Zone and, possibly, the uppermost interval of the underlying “*P. nasuta*” Zone are missing. *Iliaenus welchi* new species is described from the Whiterockian faunas of the upper Ninemile and Antelope Valley formations.

Introduction

The Whiterockian Series is the Laurentian expression of the Middle Ordovician Series. Originally described as a stage composed of five faunal zones (Cooper, 1956), the Whiterockian was elevated to the rank of series by Ross (1982). Ross and Ethington (1991) selected the section at the Whiterock Canyon Narrows, Nevada, as its stratotype and located the first appearance datum (FAD) of the conodont *Tripodus combsi* (senior subjective synonym of *T. laevis*) within the section. The Whiterock Canyon Narrows section was suggested as the global boundary stratotype with the FAD of *T. combsi* acting as the bioevent to mark the base of the Middle Ordovician (Ross and Ethington, 1992). Graptolite data, however, demonstrated that the FAD of *T. combsi* correlated to a younger graptolite interval than previously thought. Further complicating the status of the Whiterockian was the suggestion (Fortey and Droser, 1999, p. 186) that a faunal break was present, a suggestion borne out in this study, that conflicts with the International Stratigraphic Guide’s (Salvador, 1994) assertion that boundary stratotypes must exhibit “essentially continuous deposition.” Eventually the FAD of the conodont *Baltoniodus triangularis* in the Huanghuachang section, southern China, was selected as the GSSP (Global Standard Stratotype and Point) for the Middle Ordovician Series and the Dapingian Stage (Wang et al., 2009).

Location and measured sections

The stratotype for the Laurentian Whiterockian Series (Middle Ordovician) is the Whiterock Canyon Narrows section, Nevada

(Fig. 1; see Finney and Ethington, 2000, fig. 2 for detailed location). The section lies on a steep, southeast-facing slope on the north side of Whiterock Canyon within the Monitor Range.

Outcrops low on the slope at Whiterock Canyon Narrows are assigned to the Devonian Rabbit Hill Formation (Finney and Ethington, 2000). The dense, yellow weathering shale and black chert lie in fault contact with the overlying Lower Ordovician Ninemile Formation.

Low within the Ninemile Formation there occurs a laterally persistent, 15 cm thick, medium-gray, argillaceous limestone that has yielded trilobites, linguliform brachiopods, moldic gastropods, and conodonts. This bed, known informally as the “0 bed”, has served as the base of the Whiterock Canyon Narrows section for this and previous studies, including Finney and Ethington (2000). Estimates of the thickness, originally measured in feet, of the Ninemile Formation above the “0 bed” range from 42.8–52.4 m, with at least an additional 3 m of Ninemile Formation shale below. Individual limestone beds within the Ninemile Formation have been processed for conodonts (Finney and Ethington, 2000) and collected for trilobites.

Historically, Ethington (Ross and Ethington, 1991; Finney and Ethington, 2000) has measured the Ninemile Formation directly up the slope (Fig. 2, east section). The present study followed that line through the lower 24 m of the section, then traversed to the west ~25 m in order to collect trilobites through a 9 m thick interval of limestone (west section) that is not represented on the historic, east, line of section. Several limestone beds in the west section were processed for conodonts. The section ends within the Middle Ordovician Antelope Valley Limestone.

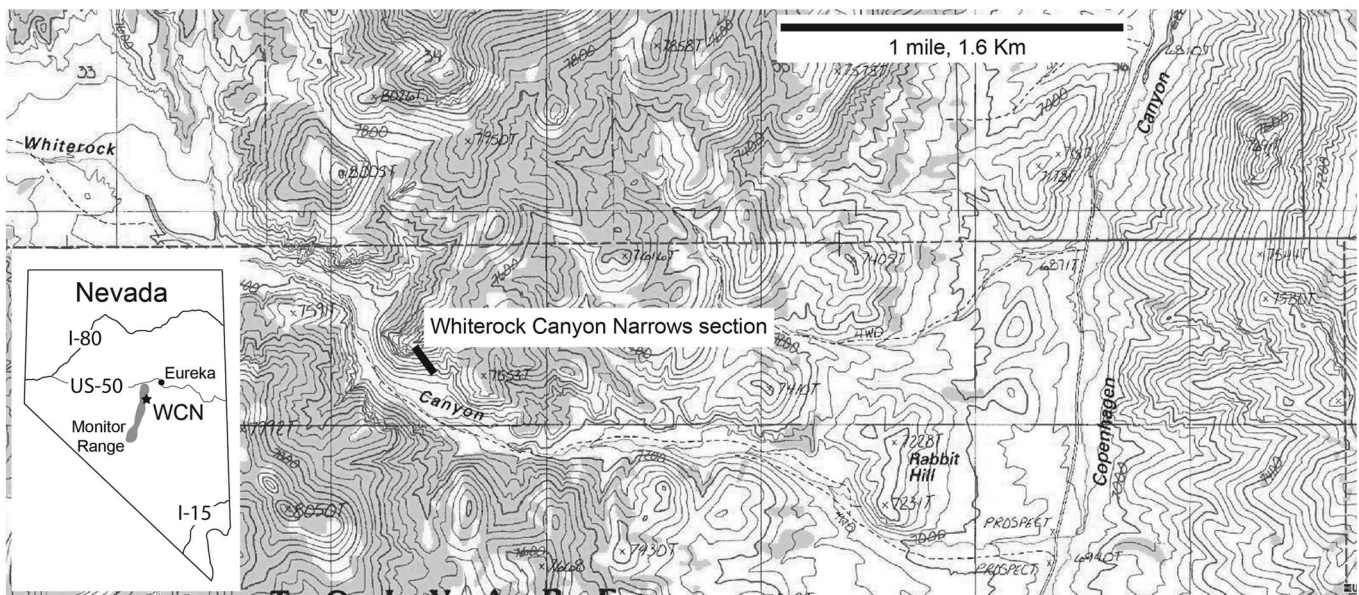


Figure 1. Index map for the White Rock Canyon Narrows section (WCN) in the Monitor Range, Nevada (inset), and showing access from Copenhagen Canyon on the topographic base. The section is located in the NW $\frac{1}{4}$, sec. 3, T. 49 N., R. 16 W. on the Horse Heaven Mountain 15' Quadrangle (UTM grid Zone 11, E 548, 525 m, N 4, 339, 225 m).

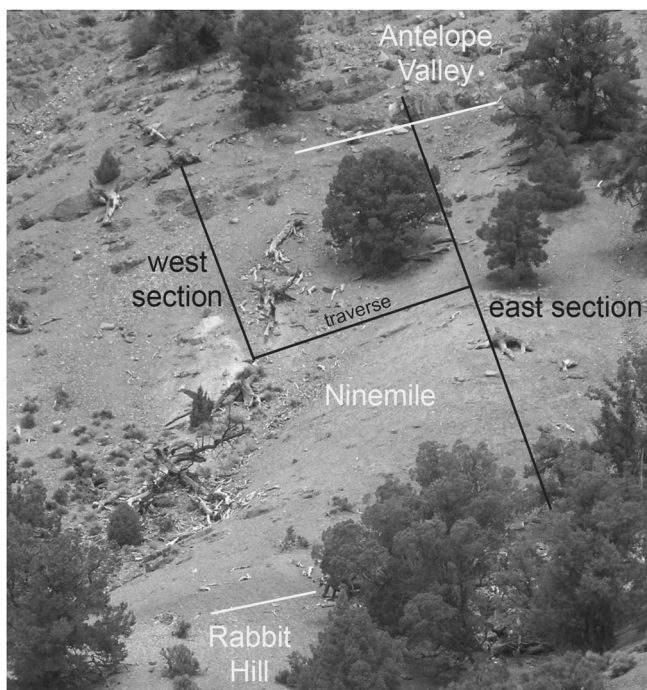


Figure 2. White Rock Canyon Narrows section, Nevada, with the historic east and new west sections highlighted.

Lithostratigraphy

The Ninemile Formation is dominated by fissile, medium-gray shale that weathers to form an extensive talus slope in the White Rock Canyon Narrow section. Laterally persistent, bedded limestone beds punctuate the talus slope. Uncommon, medium-gray, 3 to 46 cm thick, argillaceous, petroliferous, lime mudstone beds are present in the lower 36 m of the section. Laterally discontinuous wackestone and packstone beds that have yielded

trilobite, echinoderm, and linguliform brachiopod bioclasts are interbedded with shale in the upper 10 m of the Ninemile Formation. Texturally, these upper limestones are similar to those of the overlying Antelope Valley Limestone. One or more hardgrounds are suggested within these upper Ninemile Formation limestones by the presence of dark-gray bedding surfaces to which echinoderm holdfasts are attached. Additionally, intervals of the lower talus slope are armored by nodular limestone clasts that weather to yellowish gray. The nodular limestones have yielded articulated trilobites and echinoderms along with rare graptolites.

The base of the overlying Antelope Valley Limestone is placed at the base of the lowest, laterally continuous, 1.5 m thick bed of wackestone to packstone. This bed forms a prominent bench on the slope. The Antelope Valley Limestone is divisible into an oncolitic middle member and a lower member that includes lime mudstone to grainstone interbedded with minor shales (Ross and Ethington, 1991).

Biostratigraphy

Brachiopod biostratigraphy.—Cooper (1956) outlined the concept of the *Orthidiella* brachiopod Zone, based upon the presence of the eponymous genus, as the lowest zone of his White Rockian Stage. Cooper conjectured that this zone, in part, filled an evolutionary gap between the brachiopod faunas of the former Canadian (Lower Ordovician) and Chazyan (Middle Ordovician) series in eastern Laurentia at the Sauk-Tipppecanoe sequence unconformity of Sloss (1963). Following the practice of the time, however, he did not record specific stratigraphic distribution for his materials or define its zonal boundaries. Subsequently, the *Orthidiella* Zone was correlated with trilobite Zone L of Ross (1951) and the *Orthis subalata* brachiopod Zone of Hintze (1953) of Idaho and Utah (Fig. 3). More recently this interval in Utah has been treated as the *Orthidiella* Zone (Ross and Ethington, 1992) and the *Paralenorthis-Orthidiella* Zone (Ross et al., 1997).

Ibex Region, western Utah						
1	2	3	4	5	6	7
980	Kanosh Sh.	Zone M	<i>Pseudoolenoides dilectus</i> trilobite Zone	Rangerian Stage	Whiterockian Series	<i>Tripodus combsi</i> conodont Zone
960		Zone L <i>Orthis subalata</i> Zone (Hintze, 1953) or <i>Paralenorthis - Orthidiella</i> Zone (Ross et al., 1997)	<i>Psephosthenaspis glabrior</i> trilobite Zone			
940	<i>Psephosthenaspis pseudobathyrus</i> trilobite Zone					
920	<i>Ps. microspinosa</i> Zone					
900	Wah Wah Ls.	Zone K	Unstudied interval (Adrain et al., 2009)	Blackhillsian Stage	Ibexian Series	<i>Reutterodus andinus</i> conodont Zone
880		Zone J	" <i>Pseudocybele nasuta</i> " trilobite Zone			
860		<i>Pseudocybele nasuta</i> trilobite Zone	<i>Pseudocybele paranasuta</i> Zone			
meters above base of composite section	Fillmore Fm.	Zone I	Barren interval	Blackhillsian Stage	Ibexian Series	<i>Reutterodus andinus</i> conodont Zone
820			<i>Pr. ibexensis</i>			

Figure 3. Biostratigraphic framework for the Lower-Middle Ordovician boundary in Utah and Nevada. The gray interval in the Whiterock Canyon Narrows columns suggests the extent of the sub-Whiterockian lacuna. Abbreviations: AV—Antelope Valley Limestone; *Pr.*—*Presbynileus*; *Ps.*—*Psephosthenaspis*. Columns 1, 2, 5, 6, 7 after Ross et al. (1997); column 3 after Ross (1951), Hintze (1953), and Ross et al. (1997); column 4 after Fortey and Droser (1996), Adrain et al. (2009), and Adrain et al. (2012).

Trilobite biostratigraphy.—A classic succession of silicified trilobites from Idaho and Utah has served as the basis of the zonation of the Lower and lower Middle Ordovician strata in Laurentia (Fig. 3).

These zones were given letter designations (Zones A–M) when developed by Ross (1951) with taxon-based names subsequently provided by Hintze (1953). Adrain et al. (2009) recollected strata

assigned to the latest Ibexian Zone J (the *Pseudocybele nasuta* trilobite Zone) and were able to divide it into three more finely resolved intervals, in ascending order: the *Pseudocybele paranasuta* Zone, a restricted “*P. nasuta*” Zone, and an uppermost unstudied interval. Unfortunately, the basal Whiterockian trilobite faunas of the overlying Zone L (the *Orthis subalata* brachiopod Zone in Utah) are poorly silicified and were understudied until the work of Fortey and Droser (1996). In examining calcareous, “crack out” material they were able to establish a succession of 3 trilobite subzones based upon species of the trilobite *Psephosthenaspis*: the *P. microspinosa*, *P. pseudobathyurus*, and *P. glabrior* subzones (in succession). Adrain et al. (2012) subsequently elevated these subzones to zones.

The trilobite faunas recovered from the Whiterock Canyon Narrows section in this study (Fig. 4) resolve neatly into two components. The collections from the lower Ninemile Formation include species of the trilobite *Lachnostoma*, a genus that appears to be restricted to the “*Pseudocybele nasuta*” Zone (see Adrain et al., 2009). By definition, trilobites documented by Fortey and Droser (1999) from the lower Antelope Valley

Limestone are Whiterockian. The present study increases the documented diversity in the Antelope Valley Limestone in this section by five species and extends the ranges of previously identified species downward into the uppermost Ninemile Formation in the collections in the west section. While no specimens of *Psephosthenaspis* were recovered from Whiterock Canyon, the recovery of *Pseudomera arachnopyge* (Fortey and Droser, 1996) allows this Whiterockian fauna to be correlated with the *Psephosthenaspis pseudobathyurus* Zone from Ibex.

Conodont biostratigraphy.—Ethington and Clark (1971, 1981) collected conodonts from the entire Lower Ordovician and lower Middle Ordovician succession from Ibex, Utah. They were able to integrate the bases of their thirteen conodont zones and intervals (Ethington and Clark, 1981) with the boundaries in Hintze’s (1953) trilobite zonal succession in order to produce an integrated faunal zonation for the region (Ross et al., 1997). The latest Ibexian rocks at Ibex, Utah, are assigned to the *Reutterodus andinus* conodont Zone (Ross et al., 1997).

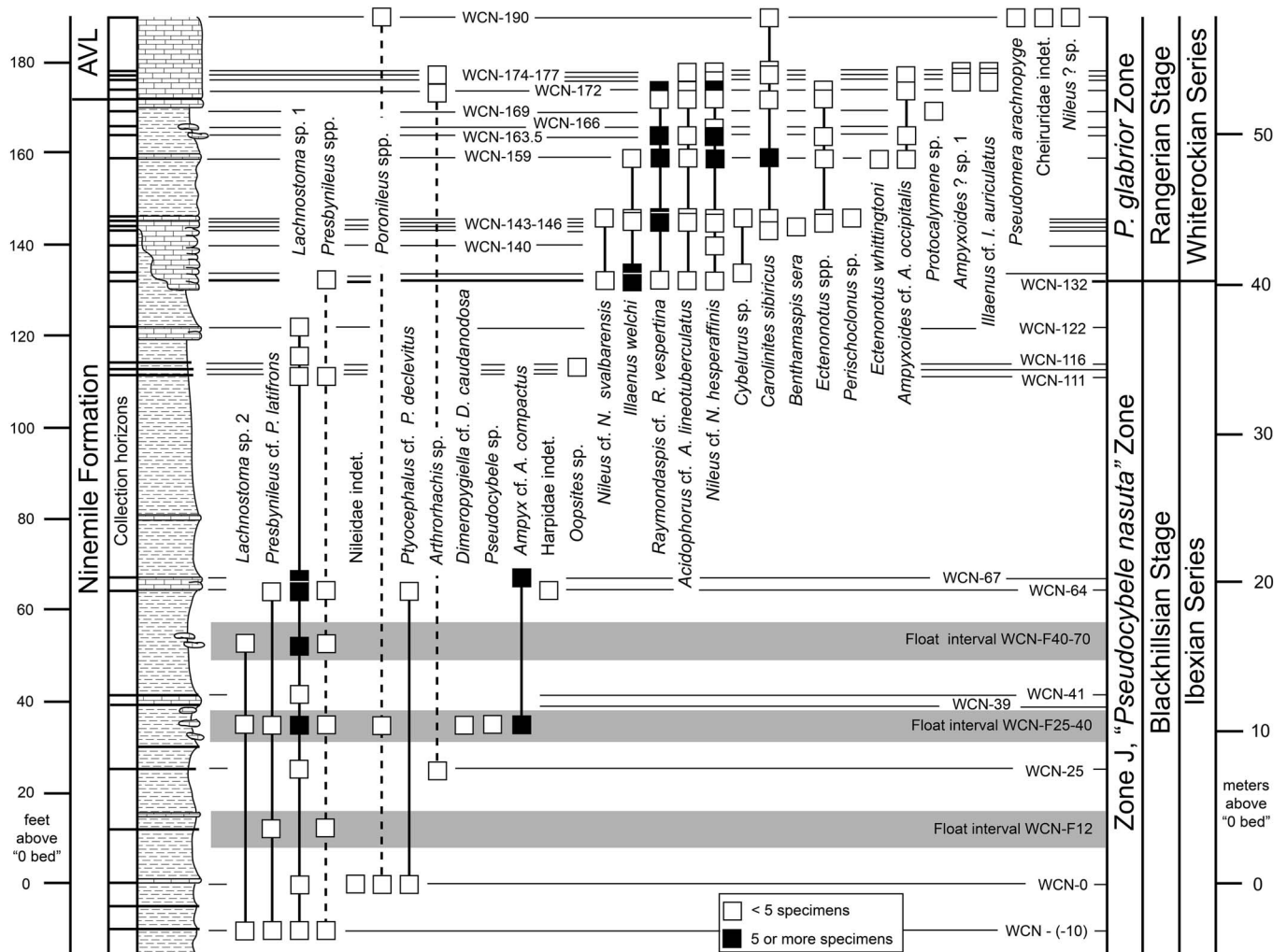


Figure 4. Trilobite species range chart for the Whiterock Canyon Narrows section, Nevada. Collections from WCN-(-10) to WCN-122 were recovered from the eastern sections while collections WCN-132 to WCN-190 were recovered from the western section. Species ranges are connected with solid line, generic ranges are connected with dashed line. Gray shading indicates intervals within which nodular limestone was recovered from float. Abbreviations: AVL—Antelope Valley Limestone; *P.*—*Psephosthenaspis*.

Ross et al. (1997) revised the conodont biozonation for the Ibexian and lower Whiterockian Series at Ibex and introduced the *Tripodus laevis* conodont Zone to replace the former *Microzarkodina flabellum*–*Tripodus laevis* interval of Ethington and Clark (1981). The First Appearance Datum (FAD) of *T. laevis*, a horizon that also served to mark the base of the Middle Ordovician, served to mark the base of this zone. The name of the eponymous species was synonymized with *T. combsi* (Bradshaw), with the acceptance by Sweet et al. (2005) of an earlier reconstruction (Stouge, 1984) of the elements in the apparatus of *Tripodus* Bradshaw. Ross and Ethington (1991, 1992) documented the FAD of *T. combsi* from the Whiterock Canyon Narrows section at the base of the Antelope Valley Limestone, emplaced a “spike” in the section to indicate the base of the Whiterockian Series, and suggested that it might serve as the GSSP for the middle series of the Ordovician. Subsequent work revised the FAD of *T. combsi* downward 3 m (10 feet) into the underlying Ninemile Formation (Fig. 3; Finney and Ethington, 2000). Ultimately, analysis of a small graptolite fauna from the Whiterock Canyon Narrows section indicated that the FAD of *T. combsi* occurred higher in the graptolite succession than previously understood, which disqualified it to serve as the GSSP.

Tripodus combsi was recovered from the western section at the Whiterock Canyon Narrows (Fig. 5) from a horizon 11.8 m below the top of the Ninemile Formation. Additional collections within the overlying Ninemile Formation yielded a fauna typical of the *Tripodus combsi* Zone. A subjacent collection from the western section yielded *Reutterodus andinus*, the eponymous species for the underlying *Reutterodus andinus* conodont Zone. Three additional collections (8–20 m) that were resampled from the eastern section yielded *Juanognathus variabilis* and *Parapanderodus asymmetricus*. These latter taxa are known to be associated with *R. andinus* in the Ibex region, Utah (Ross et al., 1997, p. 26, pl. 1), which suggests that the base of the *R. andinus* Zone may extend down section to ~8 m above the “0 bed” within the section.

The presence of a sub-Whiterockian unconformity in the upper Ninemile Formation at Whiterock Canyon Narrows.—Continuity of deposition within the Whiterock Canyon Narrows section has been a contentious issue. Adrain and Fortey (1997, p. 80) and Fortey and Droser (1999, p. 186) provided trilobite data suggestive of a hiatus. Finney and Ethington (2000) and Loch (2002), however, asserted that evolutionary conodont lineages and lack of physical evidence argued for continuous deposition across the base of the Whiterockian Series. Examination of parallel sections provides a final resolution to this question and establishes an approximate position of a cryptic unconformity at the base of the Whiterockian at its stratotype.

In the historic (Figs. 2, 6; east section) ascent of the Whiterock Canyon Narrows section, shale dominates the uppermost 12 m of the Ninemile Formation. The first appearance (FAD) of *Tripodus combsi* occurs 3 m below the top of the Ninemile Formation (Finney and Ethington, 2000). This horizon defines the base of the Whiterockian Series (Ross and Ethington, 1991). Fortey and Droser (1999) described a suite of 13 trilobite species from the lower Antelope Valley Limestone above this horizon that must be considered as Whiterockian along with the brachiopod species

listed by Cooper (1956). Fortey and Droser (1999) identified the Ibexian trilobite *Lachnostoma latucelsum* from 6 m below the top of the Ninemile Formation on this ascent.

The traverse westward to a second ascent (Figs. 2, 6; west section) passes through a nine-meter-thick package of laterally discontinuous wackestone and grainstone that is overlain by shale. Trilobites and conodonts recovered from this west section place the three biostratigraphic horizons discussed above at different positions within the Ninemile Formation. *Tripodus combsi* has its FAD 9 m lower in the section at 11.8 m below the base of the Antelope Valley Limestone. Whiterockian trilobites extend 11.8 m below the base of the Antelope Valley Limestone. The last appearance (LAD) of *Lachnostoma* spp. occurs 37.2 m below the base of the Antelope Valley Limestone, 11.2 m lower than on the eastern ascent. These six data points allow the approximate position of a cryptic unconformity to be traced between the two sections (dashed line in Fig. 6) with a relief of 9 m. The presence of this unconformity at the Whiterock Canyon Narrows section, however, should not be used to suggest the presence of a regionally significant unconformity without further data. Instead, an alternative section that includes a more continuous depositional record (Salvador, 1994), as well as the FAD of *Tripodus combsi*, needs to be identified to serve as a better boundary stratotype for the Whiterockian.

A model can be developed for the formation of this sub-Whiterockian unconformity. The sequence begins with deposition of Ninemile Formation shale with bedded and nodular limestone during the late Ibexian in a ramp or outer continental-slope setting below wave base (Ross et al., 1989). Regression and a sea-level drop in the late Ibexian to earliest Whiterockian (Nielson, 1992; Wang et al., 2009; Landing, 2012) resulted in the scouring of a localized channel into the Ninemile Formation shale. Transgression and rapid progradation of lower Antelope Valley-type limestone (Ross et al., 1989) filled the channel through the periodic influx of wackestone and grainstone, with occasions of hardground formation, that interrupted intervals of shale deposition. Transgression and progradation of upper-slope limestone climaxed in the formation of outer continental-shelf oncolite complexes of the middle member of the Antelope Valley Limestone (Ross et al., 1989).

Repositories and institutional abbreviations.—All trilobite types and illustrated specimens are curated at the Carnegie Museum of Natural History (CM) in Pittsburgh, Pennsylvania. Occurrence data are keyed by measured section abbreviation and measured distance (in original feet) above the base of the section (ex. WCN-137). Some trilobite material was collected as float (F) from the slopes in the Ninemile Formation for comparative purposes with their approximate stratigraphic position indicated (e.g., WCN-F25–40). Abundance data are recorded as (cranidia-pygidia-librigenae) for each collection horizon.

Systematic paleontology

Morphologic terms used follow Whittington (1997). Most taxa are held in open nomenclature due to the small and often fragmentary nature of the specimens recovered. The contrast in

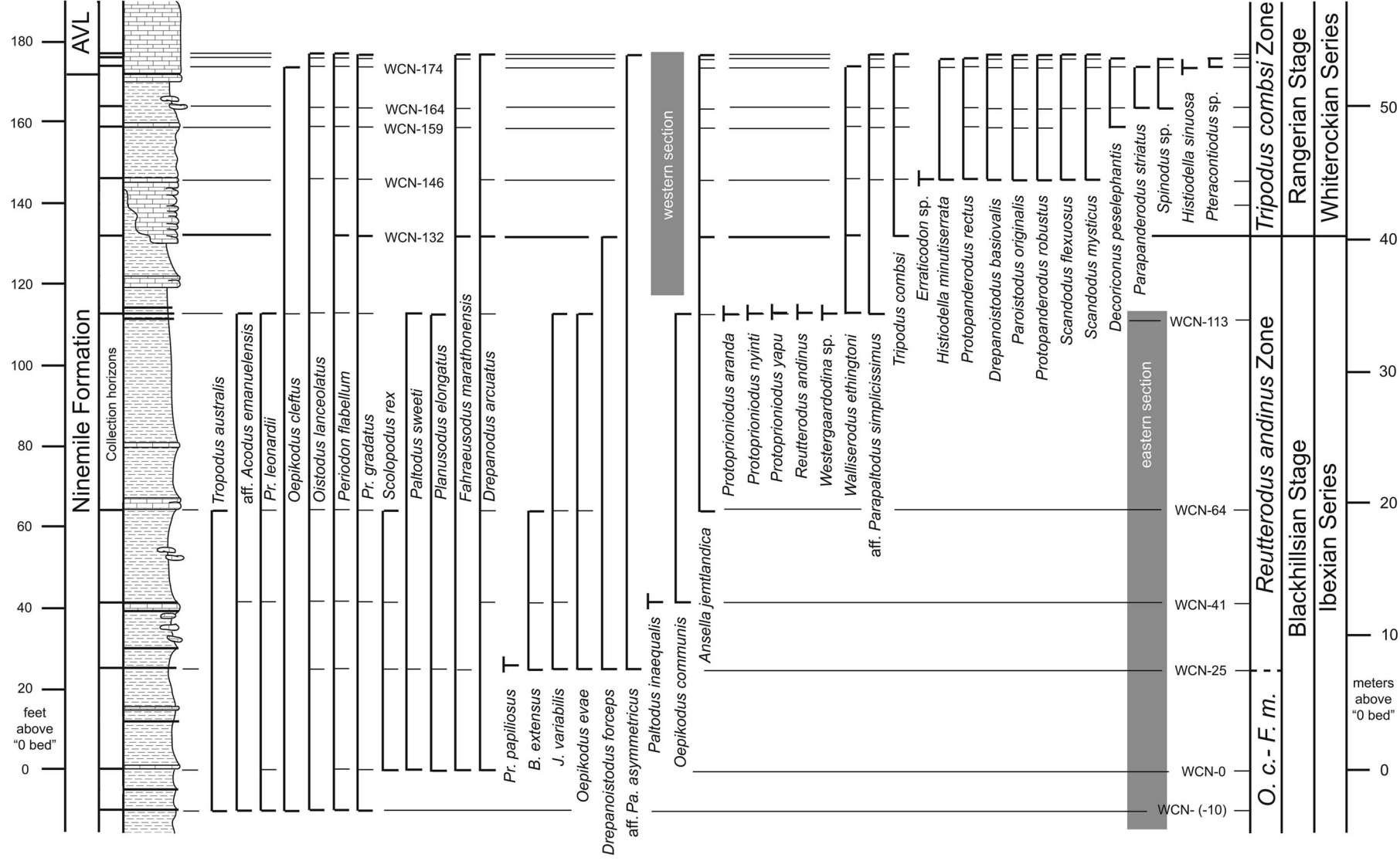


Figure 5. Conodont species range chart for the Whiterock Canyon Narrows, east section (0–20 m) and west section (30–55 m), Nevada. Base of the *Reutterodus andinus* Zone based upon Finney and Ethington (2000). Abbreviations: AVL—Antelope Valley Limestone; *B*—*Bergstroemognathus*; *D*—*Drepanoistodus*; *J*—*Juanognathus*; *O. c. - F. m.*—*Oepikodus communis*-*Faraeusodus marathonsensis* conodont Zone; *Pa*—*Parapanderodus*; *Pr*—*Protopanderodus*.

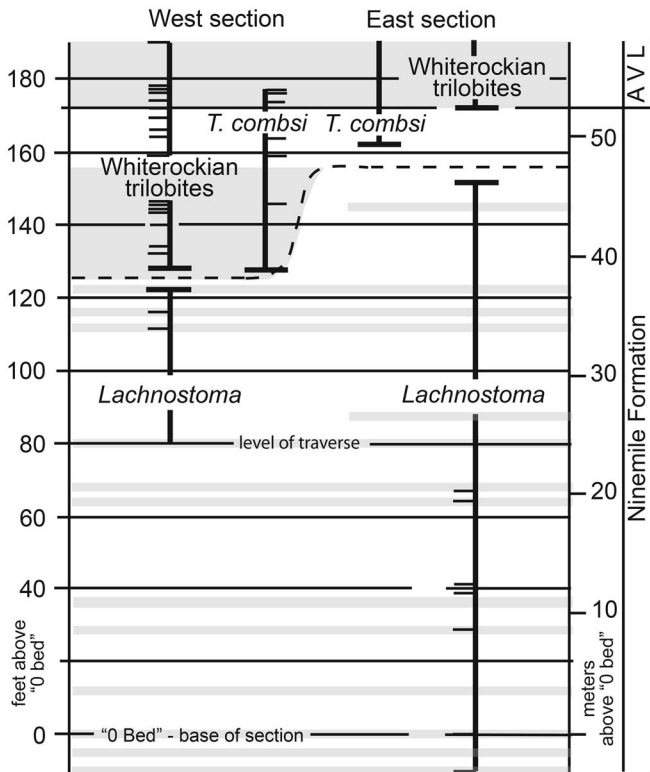


Figure 6. Distribution of selected taxa to highlight position of cryptic, sub-Whiterockian unconformity (dashed line) in the Ninemile Formation, Whiterock Canyon Narrows section, Nevada. Gray shading indicates limestone within the section. Distribution of trilobites in the eastern section above 25 m is from Fortey and Droser (1999). Abbreviation: AVL—Antelope Valley Limestone; *T. Tripodus*.

preservation when trying to compare mechanically prepared material from Whiterock Canyon and silicified materials from the Ibex region, Utah, exacerbated these problems.

Phylum Arthropoda Latreille, 1829
 Class Uncertain
 Order Agnostida Salter, 1864
 Family Metagnostidae Jaekel, 1909
 Genus *Arthrorhachis* Hawle and Corda, 1847

Type species.—*Battus tardus* Barrande, 1846, p. 35, from the Kraluv Dvur Formation of the Czech Republic.

Arthrorhachis sp.
 Figure 7.1, 7.2

Remarks.—Three poorly preserved cranidia from WCN-F25–40, WCN-174, and WCN-178 appear similar to *Trinodus*

sp. 1 of Ross (1967, p. D9, pl. 3, fig. 19, 1972, p. 28, pl. 11, fig. 15) from the Antelope Valley Limestone in Nevada. The specimens from the Whiterock Canyon Narrows share the broad border and border furrow, the weak F2 furrow, and ovate glabella illustrated by Ross. Fortey (1980, p. 27), however, restricted *Trinodus* McCoy, 1846, to type and asserted that *Arthrorhachis* can accommodate species formerly assigned to *Trinodus*.

Class Trilobita Walch, 1771
 Order Asaphida Fortey and Chatterton, 1988
 Family Asaphidae Burmeister, 1843
 Genus *Lachnostoma* Ross, 1951

Type species.—*Lachnostoma latucelsum* Ross, 1951, p. 95, by original designation, from the Ibexian Garden City Formation of northern Utah.

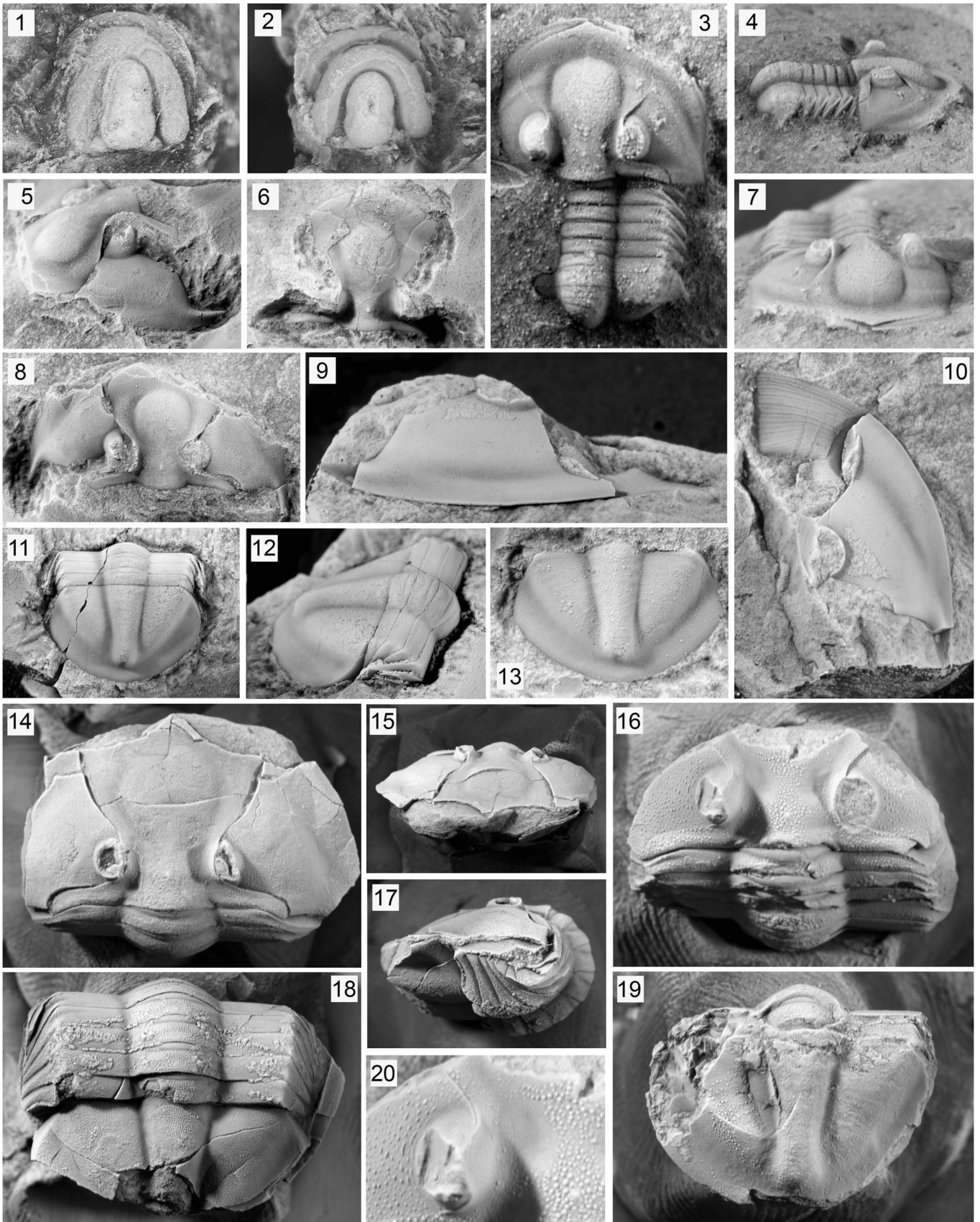
Lachnostoma species 1
 Figure 7.3–7.13

- cf. 1989 *Lachnostoma latucelsum* Ross; Dean, p. 39, pl. 32, figs. 10–15, pl. 33, figs. 1–16.
- cf. 1996 *Lachnostoma latucelsum*; Fortey and Droser, fig. 7.12, 7.13.

Material and occurrence.—Total of 28 cranidia, 67 pygidia, 29 librigenae, and seven articulated individuals. Present in the Ibexian Ninemile Formation in WCN(-10) (3-0-0), WCN-0 (1-0-0), WCN-2 (0-1-0), WCN-25 (1-1-0), WCN-F25-40 (11-41-15 and seven articulated individuals), WCN-39 (0-0-1), WCN-F40-70 (0-3-2), WCN-41 (0-1-1), WCN-64 (7-6-4), WCN-67 (5-10-6), WCN-111 (0-3-0), WCN-116 (0-1-0), and WCN-122 (0-1-0).

Remarks.—Specimens of *Lachnostoma* sp. 1 examined from the Ninemile Formation are united in their smooth prosopon. *Lachnostoma* sp. 1 differ from the type material (*Lachnostoma latucelsum* Ross, 1951, p. 95–97, pl. 21, figs. 13–25, pl. 22, figs. 3, 6–8, pl. 23, figs. 5, 6; Adrain et al., 2009, figs. 21Q, 21U) and contemporaneous material from Utah (Hintze, 1953, p. 187, pl. 18, figs. 4–16), however, in that the glabella appears more constricted between the palpebral lobes. The anterior course of the facial sutures in *L.* sp. 1 forms a more even, broad curve than in *L. latucelsum*. The maximum width of the cranidium (tr.) of *L.* sp. 1 is approximately 90% the total cranidial length, whereas in the type the maximum width and length are nearly equivalent. The pygidia of *L.* sp. 1 differs from the type material in having axial furrows that are recurved distally, rather than straight, which results in the distal end of the axis being more convex and pronounced. In these aspects, *L.* sp. 1 compares more closely to the specimen previously illustrated as *L. latucelsum*

Figure 7. *Arthrorhachis* Hawle and Corda, 1847 and *Lachnostoma* Ross, 1951. (1, 2) *Arthrorhachis* sp., (1) dorsal view (×15.0) testate cephalon, Antelope Valley Limestone, WCN-178, CM 59000; (2) dorsal view (×15.0) testate cephalon, Ninemile Formation, WCN-F25, CM 59001. (3–13) *Lachnostoma* sp. 1, all from Ninemile Formation, (3, 4, 7) palpebral (×6.4), lateral (×4.7), and anterior (×6.5) views, testate carapace, WCN-F40, CM 59002; (5, 8) lateral oblique (×2.8) and palpebral (×2.4) views of testate, partially disarticulated cephalon, WCN-F25–40, CM 59003; (6) palpebral view (×3.0) of partially exfoliated cranidium, WCN-F25–40, CM 59004; (9, 10) lateral (×4.9) and dorsal (×4.1) views of testate librigena, WCN-F40–70, CM 59005; (11, 12) dorsal (×1.8) and lateral oblique (×2.6) views of testate, enrolled, thoraco-pygidium, WCN-F25–40, CM 59006; (13) dorsal view (×4.5) of testate pygidium, WCN-F25–40, CM 59007. (14–20) *Lachnostoma* sp. 2, all from Ninemile Formation, (14, 15, 17, 18) palpebral (×2.9), anterior (×1.8), left lateral (×2.2), and dorsal pygidial (×1.8) views of testate, slightly compacted, enrolled carapace, WCN-F40–70, CM 59008; (16, 19, 20) palpebral view (×2.5) of cephalon, view dorsal (×2.5) of pygidium, and palpebral (×6.8) enlargement of testate, fragmentary, enrolled carapace, WCN-F40–70, CM 59009.



by Fortey and Droser (1996) from the Ninemile Formation and those identified by Dean (1989) from the Outram and Skoki formations of Alberta, Canada.

Lachnostoma species 2
Figure 7.14–7.20

Material and occurrence.—Present in the Ibexian Ninemile Formation in WCN-(-10) (1-0-0), WCN-F25–40 (0-0-1 and one articulated carapace), and WCN-F40–70 (0-1-0 and one articulated carapace).

Remarks.—The presence of the granulose prosopon on *Lachnostoma* sp. 2 was used to distinguish it from similar sized specimens of *Lachnostoma* sp. 1. Additionally, two pairs of broad depressions along the weakly impressed axial furrows and steeply inclined palpebral lobes serve to further distinguish *L.* sp. 2.

Dean (1988, p. 5, pl. 1.3, figs. 4, 6–9, 11) illustrated *Lachnostoma* n. sp. from the McKay Group of British Columbia. *Lachnostoma* n. sp. compares with *Lachnostoma* sp. 2 in the presence of two broad depressions along the axial furrow. These depressions in *L.* n. sp., however, lie at the posterior end of the palpebral lobes and behind the glabellar tubercle. Further, *L.* n. sp. lacks a granular prosopon and the glabella is not as well defined between the palpebral lobes.

Genus *Presbynileus* Hintze, 1954

1953 *Paranileus* Hintze. [Junior homonym of *Paranileus* Kobayashi, 1951]

Type species.—*Paranileus ibexensis* Hintze, 1953, p. 199–200, by original designation, from the Ibexian Fillmore Limestone of the Ibex region of Utah.

Diagnosis.—See Jaanusson in Moore, 1959, p. O343.

Remarks.—Hintze (1953) erected the genera *Pseudonileus* and *Paranileus* from the Ibex region of Utah for two generally effaced, slightly to moderately convex asaphids. Hintze separated the genera on the basis of their hypostomal shape, degree of convexity (sag.), curvature of the anterior facial suture, and relative proportions and position of the palpebral lobes. Both names were preoccupied and Hintze (1954) proposed replacement names for both (*Protopresbynileus* and *Presbynileus*, respectively). Jaanusson (in Moore, 1959) moved both taxa to the rank of subgenus within *Presbynileus*, a practice followed by Fortey (1975) and Dean (1989). We prefer, however, to follow Hintze (1953, 1954) and, subsequently, Fortey and Droser (1999) in retaining these two taxa at the rank of genus.

Dean (1989) erected the species *Presbynileus (Presbynileus) latifrons*, although without benefit of an associated hypostome. *Presbynileus latifrons*, however, exhibits axial furrows on both the cranidium and pygidium that are moderately impressed, moderately inclined palpebral areas, a steeply declined frontal lobe of the glabella, and a moderately convex pygidial axis. Further, there is a pronounced set of terrace lines limited to the frontal lobe of the

glabella. These stand in contrast to the type species for both *Protopresbynileus* and *Presbynileus*.

The cranidium illustrated by Fortey and Droser (1999, fig. 7.16) from the basal Antelope Valley Limestone as *Protopresbynileus* cf. *glaber* exhibits moderately impressed axial furrows, a steeply declined frontal glabellar lobe, and terrace lines on the frontal lobe. These characters conform more closely to *P. latifrons* than to *P.?* *glaber* Fortey (1975, p. 19–21, pl. 9, figs. 1, 2, 4) in their convexity, the impression of the axial furrows, and the width (tr.) between the axial furrows at the palpebral lobes. Additional cranidia recovered from the Ninemile Formation (Fig. 8.8–8.10) exhibit the same inclination to the frontal lobe, terrace lines, and moderately impressed axial furrows. Were further specimens exhibiting these characters and additional sclerites available, these Nevada materials (in conjunction with *P. latifrons* and *P. glaber*) may represent a new genus.

Presbynileus cf. *P. latifrons* Dean, 1989
Figure 8.1–8.3, 8.11, 8.14, 8.15

cf. 1989 *Presbynileus (Presbynileus) latifrons* Dean, p. 40, pl. 34, figs. 1–4, 6, 7, 9–13, pl. 35, figs. 1–11.

Material and occurrence.—Total of one cranidium, four pygidia, and two librigenae from the Ninemile Formation in WCN-(-10) (0-1-1), WCN-F12 (0-3-0), WCN-F25–40 (0-2-0), WCN-64 (0-2-1), and WCN-111 (1-0-0). Also known from the *Pseudocybele nasuta* Zone (Zone J) of the Outram Formation of Alberta, Canada, (Dean, 1989).

Remarks.—The cranidium illustrated from the Ninemile Formation conforms in shape and convexity of the glabella (both sag. and tr.), orientation of the palpebral lobes, orientation and impression of the axial furrows, and the prosopon of coarse terrace lines to the specimens of *Presbynileus latifrons* illustrated by Dean (1989). The fragmentary nature of both the Nevada and original material makes confident assignment of the cranidia problematic. The assigned librigenae exhibit a corresponding cord-like border, broad genal angle, and downward flexure of the posterior margin seen in *P. latifrons*. The pygidia from Nevada exhibit the long, evenly tapered axis, “panderian protuberance”, and evenly convex pleural region seen from Alberta. The broad (tr.) pygidia with a long, clearly defined axis are consistent with those assigned to *Presbynileus latifrons* (Dean, 1989, pl. 34, figs. 10, 13, pl. 35, figs. 1–11). The Nevada pygidia (Figure 8.13), however, possess a more convex (tr.) axis (closer to Dean, 1989, pl. 35, figs. 7, 8).

Presbynileus spp.
Figure 8.4, 8.6, 8.11–8.15

Remarks.—Three cranidia were recovered singularly from the Ninemile Formation from WCN-F25–40 (Fig. 10.11–10.14), WCN-F40–70, and WCN-111 (Fig. 8.4, 8.6). These cranidia each exhibit the steeply declined frontal glabellar lobe bearing the terrace lines seen in *Presbynileus latifrons* Dean (1989). They each differ, however, in their width between the palpebral

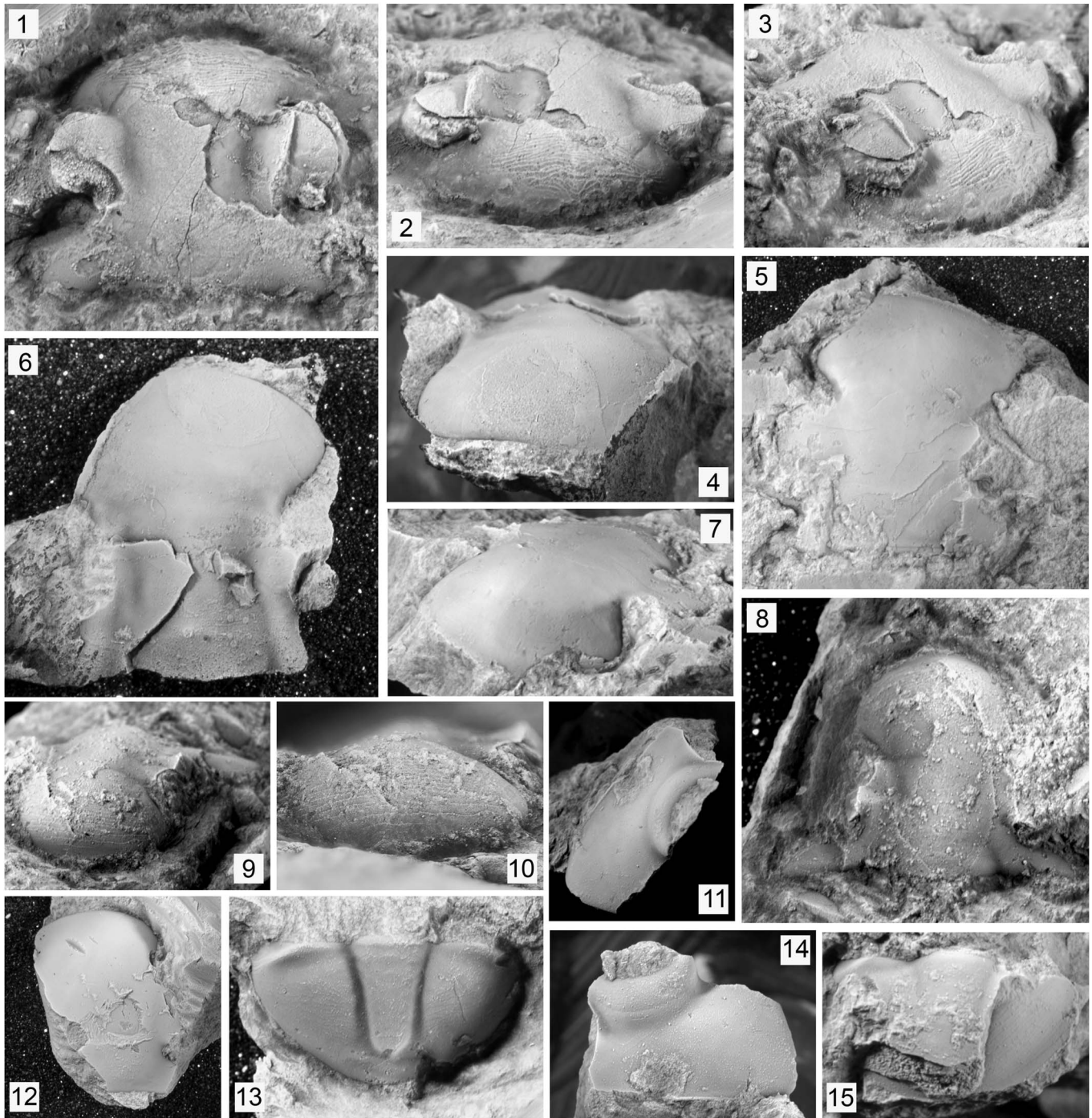


Figure 8. *Presbynileus* (Hintze, 1954). (1–3, 11, 14, 15) *Presbynileus* cf. *P. latifrons* Dean, 1989, all from Ninemile Formation, (1–3) palpebral ($\times 4.5$), anterior ($\times 4.4$), and anterior oblique ($\times 4.4$) views of largely testate cranidium, WCN-F25-40, CM 59010; (11, 14) dorsal ($\times 2.8$) and lateral ($\times 3.0$) views of testate librigena, WCN-64, CM 59011; (15) dorsal view ($\times 4.0$) of fragmentary pygidium with doublure exposed on right side, WCN-64, CM 590012. (4–10, 12, 13) *Presbynileus* spp., all from Ninemile Formation, (4, 6) anterior and palpebral views ($\times 2.5$) of large, largely exfoliated cranidium, WCN-111, CM 59013; (5, 7) palpebral ($\times 2.3$) and anterior oblique ($\times 1.6$) views of exfoliated cranidium, Ninemile Formation, WCN-64, CM 59014; (8–10) palpebral ($\times 4.8$), anterior oblique, ($\times 4.4$) and anterior view showing prosopon ($\times 7.2$) of testate cranidium, WCN-F25-40, CM 59015; (12) palpebral view ($\times 2.0$) of fragmentary, testate cranidium, WCN-132, CM 59016; (13) dorsal view ($\times 4.0$) testate pygidium, WCN-(10), CM 59017.

lobes relative to their total length and in the impression of the axial furrows.

Four additional smooth cranidia recovered singularly from the Ninemile Formation in WCN-F25-40, WCN-64, WCN-111, and WCN-132 are assigned to *Presbynileus* sp. in exhibiting a moderately declined frontal glabella lobe, weakly

impressed axial furrows, and a slight inclination of the palpebral areas. The palpebral lobes for the exfoliated cranidia from WCN-64 (Fig. 8.5, 8.7) and WCN-111 (Fig. 8.4, 8.6) are large and relatively close together, which results in a shape that is more elongate (sag.) than the specimens illustrated for *Presbynileus ibexensis* (Hintze, 1953, p. 199–200, pl. 12,

figs. 6–12) or for *Presbynileus utahensis* (Hintze, 1953, p. 200–201, pl. 13, figs. 1–4).

Four pygidia from the Ninemile Formation were recovered from WCN-(–10) (0-1-0) and WCN-F12 (0-3-0) and assigned to *Presbynileus* based upon their greater overall convexity (tr., sag.) than seen in *Protopresbynileus*. The pygidia of *Presbynileus ibexensis* (Hintze, 1953, p. 199–200, pl. 12, figs. 10a, 10b, 12a, 12b) and of *Presbynileus utahensis* (Hintze, 1953, p. 200–201, pl. 13, fig. 3a–3d), in contrast to those from the Ninemile Formation, are nearly effaced.

Genus *Ptyocephalus* Whittington, 1948

Type species.—*Ptyocephalus vigilans* Whittington, 1948, p. 567–572, by original designation, from the Pogonip Group, Antelope Range, Nevada.

Remarks.—We follow Hu (1963), Dean (1989), and Adrain et al. (2009) in the pragmatic use of *Ptyocephalus* Whittington, a taxon that is based upon the articulated carapace of *Ptyocephalus vigilans*. Although *Kirkella* Kobayashi (1942) is the senior subjective synonym of *Ptyocephalus* (Whittington, 1948; Dean, 1989), it is based on an isolated pygidia and is itself a homonym (*Kirkella* Gunnell, 1933).

Ptyocephalus cf. *P. declivitus* (Ross, 1951) Figure 9.1–9.5

- cf. 1951 *Kirkella declivita* Ross, p. 91, pl. 21, figs. 1–12, pl. 37, figs. 6, 11, 12.
cf. 1953 *Kirkella declivata* (sic); Hintze, p. 183, pl. 15, figs. 3, 4, 9–12.
cf. 1963 *Ptyocephalus declivitus*; Hu, p. 88, pl. 13, figs. 10–14.

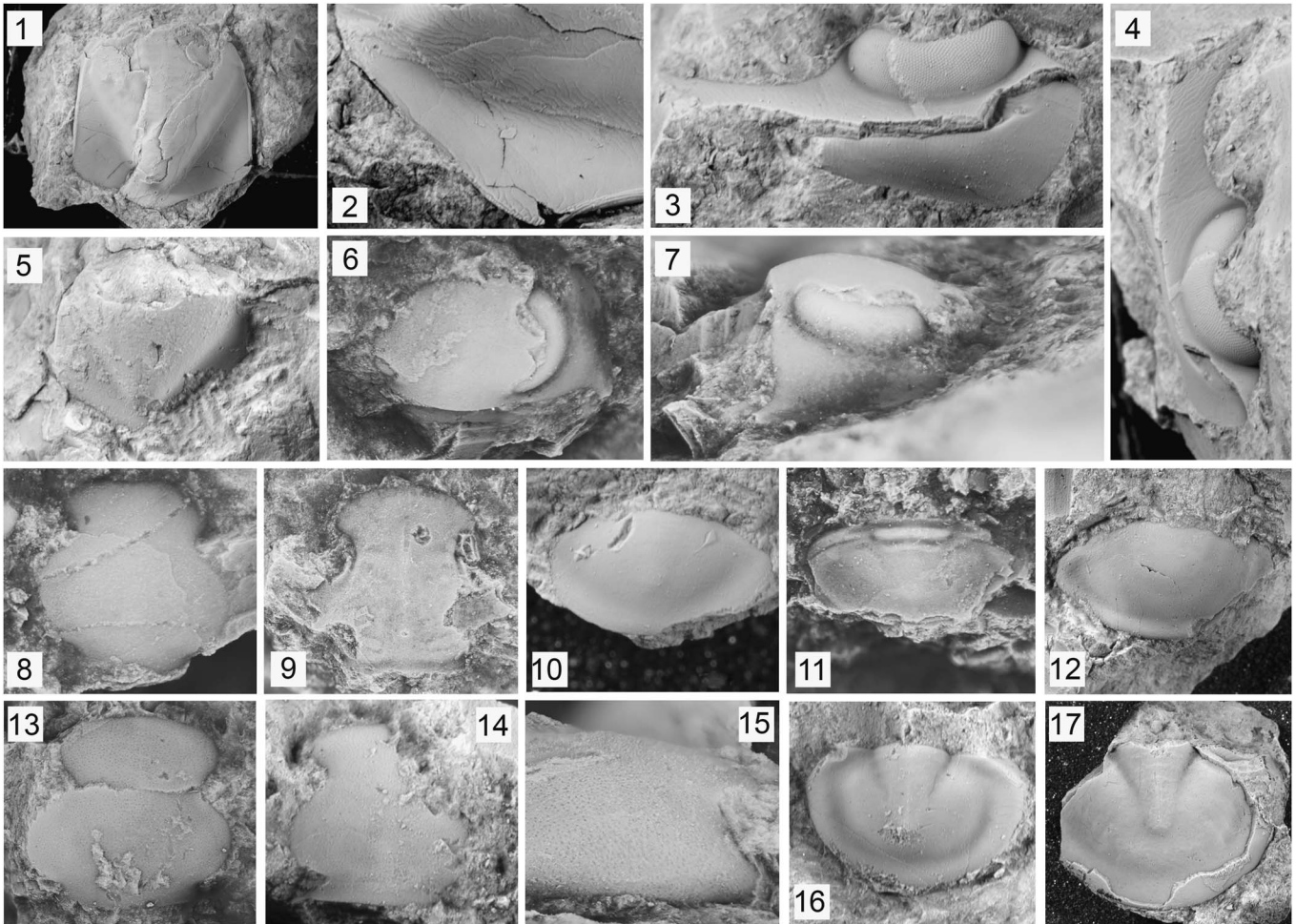


Figure 9. *Ptyocephalus* Whittington, 1948, and Nileidae Angelin, 1854. (1–5) *Ptyocephalus* cf. *P. declivitus* (Ross, 1951), all from Ninemile Formation, (1, 2) dorsal ($\times 1.3$) and lateral oblique showing prosopon ($\times 2.9$) views of testate, partially crushed pygidium, WCN-0, CM 59018; (3, 4) lateral and dorsal views ($\times 3.8$) of testate, fragmentary librigena, WCN-0, CM 59019; (5) dorsal view ($\times 2.8$) of testate, fragmentary pygidium, WCN-64, CM 59020. (6–11) *Nileus* cf. *N. hesperaffinis* Ross, 1967, (6, 7) palpebral ($\times 8.2$) and lateral oblique ($\times 11.0$) views of testate, fragmentary cephalon, Ninemile Formation, WCN-159, CM 59021; (8) palpebral view ($\times 8.1$) of testate cranium, Ninemile Formation, WCN-159, CM 59022; (9) palpebral view ($\times 6.0$) of exfoliated, fragmentary cranium, Antelope Valley Limestone, WCN-174, CM 59023; (10) dorsal view ($\times 5.3$) of testate, pygidium, Ninemile Formation, WCN-132, CM 59024; (11) dorsal view ($\times 7.3$) of exfoliated pygidium, Antelope Valley Limestone, WCN-174, CM 59025. (12) *Nileus?* sp., dorsal view ($\times 1.5$) of testate pygidium, Antelope Valley Limestone, WC-190, CM 59026. (13–15) *Nileus* cf. *N. svalbardensis* Fortey, 1975, n. comb., all from Ninemile Formation, (13) palpebral view ($\times 5.4$) of testate cranium, WCN-132, CM 59027; (14) palpebral view ($\times 5.7$) of testate, fragmentary cranium, WCN-146, CM 59028; (15) anterior view ($\times 6.7$) of testate cranium showing punctate prosopon, WCN-146, CM 5929. (16, 17) Nileidae indet., from the Ninemile Formation, WCN-0, (16) dorsal view ($\times 3.4$) of testate pygidium, CM 59030; (17) dorsal view ($\times 1.5$) of exfoliated pygidium, CM 59031.

- cf. 1989 *Ptyocephalus declivitus*; Dean, p. 41, pl. 35, figs. 12–15, pl. 36, 1–4, 6–13, pl. 37, figs. 6, 11, 12.
 cf. 2009 *Ptyocephalus declivitus*; Adrain et al., fig. 21R, 21V.

Material and occurrence.—Two pygidia and one librigena were recovered from the Ibexian Ninemile Formation in WCN-0 (0-1-1) and WCN-64 (0-1-0).

Remarks.—The pentagonal pygidial outline with an axis poorly defined by faintly impressed axial furrows conforms to the generic concept of *Ptyocephalus*. The long pygidia, approximately equal to their width, conform more in dimension to the younger species *Ptyocephalus declivitus* and *P. acclivus* (Hintze, 1953). The Ninemile Formation specimens differ from Ross' (1951), however, in having axial and ring furrows that are less well impressed. The posteriolateral pygidial corners of the Nevada material are more angular than the rounded corners in *P. acclivus* (Hintze, 1953, 185–186, pl. 14, figs. 16–17, pl. 15, figs. 1–2; Young, 1973, p. 110, 112, pl. 2, figs. 23, 24; Dean, 1989, p. 41, pl. 36, fig. 5). Ross (1951, p. 92) noted that the pygidial length of *Ptyocephalus vigilans* Whittington (1948, p. 567–572, pl. 82, figs. 1–5 for the holotype), the type species, is slightly less than the pygidial width in distinguishing it from *P. declivitus*. Adrain et al. (2009, figs. 16X, 17F, 17G, 20 F) illustrated four older *Ptyocephalus* species in open nomenclature. The pygidia of these species, however, are uniformly shorter relative to their width than the Ninemile Formation pygidia.

Family Nileidae Angelin, 1854
 Genus *Nileus* Dalman, 1827

Type species.—*Asaphus (Nileus) armadillo* Dalman, 1827, by monotypy, from the Hølen Limestone of Sweden.

Nileus cf. *N. hesperaffinis* Ross, 1967
 Figure 9.6–9.11

- cf. 1967 *Nileus hesperaffinis* Ross, p. D13, pl. 4, figs. 18–25.
 cf. 1999 *Nileus hesperaffinis*; Fortey and Droser, p. 193, fig. 7.1–7.7.

Material and occurrence.—Total of 27 cranidia, 36 pygidia, and three librigenae. Present in the Ninemile Formation in WCN-132 (0-4-0), WCN-140 (1-0-0), WCN-145 (0-4-0), WCN-146 (1-2-0), WCN-159 (11-10-2), WCN-163.5 (3-2-0), and WCN-166 (0-1-1). Present in the Antelope Valley Limestone in WCN-172 (2-2-0), WCN-174 (9-8-0), WCN-176 (0-1-0), and WCN-178 (0-2-0). This extends the known range for this taxon at the Whiterock Canyon Narrows, Nevada (Fortey and Droser, 1999) from the Antelope Valley downward into the Ninemile.

Remarks.—The cranidia and pygidia of *Nileus* cf. *N. hesperaffinis* from the Ninemile Formation conform completely to those illustrated previously from the Antelope Valley Limestone (Fortey and Droser, 1999). Ontogenetic variation is evident in the development of the genal spine. The spine is most pronounced in the smallest specimen (Fig. 10.2, 10.3) and is reduced as the specimen size increases (Ross, 1967, pl. 4, fig. 19; Fortey and

Droser, 1999, fig. 7.4) until lost in the largest illustrated specimen (Fortey and Droser, 1999, fig. 7.1).

Nileus cf. *N. hesperaffinis* differs in minor manners from *N. hesperaffinis* Ross (1967) in having a cranidium that appears longer than wide, in a slightly narrower pygidial border, and in the presence of a very faintly defined pygidial axis. These differences, however, may be of preservational or ontogenetic in origin.

Nileus cf. *N. svalbardensis* Fortey, 1975, new combination
 Figure 9.13–9.15

- cf. 1975 *Nileus orbiculatooides svalbardensis* Fortey, p. 43, pl. 11, figs. 1–13.

Material and occurrence.—Total of eight cranidia and one hypostome from the Whiterockian Ninemile Formation in WCN-132 (4-0-0) and WCN-146 (4-0-0 + one hypostome).

Remarks.—Several small, punctate cranidia were recovered that lacked evidence of axial furrows or an inflection passing laterally (tr.) from the axis to the palpebral lobes. The palpebral lobes of these individuals were relatively large and set posteriorly, which resulted in short (exsag.) posterior areas. *Poronileus* Fortey (1975, p. 51) exhibits pronounced punctae, but has palpebral lobes that are smaller and set more anteriorly along with faintly impressed axial furrows.

The proportions of the palpebral lobes, the short (exsag.) posterior areas, and the lack of glabellar furrows seen in these specimens conform to *Nileus* Dahlman (1827). Within *Nileus*, Fortey (1975) described two punctate species: *Nileus porosus* and *Nileus orbiculatooides svalbardensis*. *Nileus porosus* Fortey (1975, p. 44–46, pl. 12, figs. 1–14) exhibits faintly impressed axial furrows, slightly inclined palpebral lobes that are set medially, and long (exsag.) posterior areas. These characters are not seen in the cranidia from Nevada. Fortey (1975) erected *Nileus orbiculatooides svalbardensis* as a subspecies of *N. orbiculatooides* Schrank, 1972. Nielsen (1995, p. 239), however, excluded *N. svalbardensis* as a subspecies of *N. orbiculatooides*. While Nielsen (1995) suggested that *N. svalbardensis* may be related to a “*Nileus depressus* group,” he did not formally reassign it as a subspecies within that group. We elevate this subspecies to species rank and treat it as *N. svalbardensis*, pending further discussion. The short posterior areas and larger, medially positioned, declined palpebral lobes seen in the Nevada material are consistent with *N. svalbardensis* Fortey (1975). *Nileus* cf. *N. svalbardensis* from Nevada, however, appears to exhibit an anterior course of the facial suture that diverges at less of an angle to the axis than *N. svalbardensis* and that passes into broad, rather than tight, curve as the facial suture approaches the axis.

Whittington (1965, p. 362–363, pl. 36, figs. 1–10, pl. 32, figs. 8, 11) described the punctate *Nileus? lacunosa* from the younger Table Head Group of Newfoundland, Canada. This species differs from the Nevada material in having a more quadrate cranidial outline resulting from a shorter (sag.) frontal lobe.

Nileus? sp.
 Figure 9.12

Remarks.—A single pygidium from WCN-190 from the Antelope Valley Limestone is tentatively assigned to *Nileus* based upon its transverse outline and effaced axis, which are characters highlighted by Fortey (1975, p. 40) in his diagnosis of the genus. This pygidium differs from that of *Nileus* cf. *N. hesperaffinis* (Fig. 9.10) in its larger size, the possession of a shorter (sag.) and narrower (tr.) border, and a moderate pygidial convexity (sag.). Ross (1967, p. D13, pl. 4, fig. 15) illustrated an additional *Nileus* pygidium in open nomenclature from the Antelope Valley Limestone. Ross's pygidium is more elongate and with a broader border than that illustrated here.

Nileidae indet.
Figure 9.16, 9.17

Remarks.—Two distinctive pygidia from the Ninemile Formation, WCN-0, are comparable to species of *Poronileus* Fortey (1975) in the rapidly tapering, long axis, the faintly impressed axial furrows, faintly impressed anteriormost ring furrow, and concave border. The Nevada specimens, however,

appear relatively shorter (sag.) and have a border furrow that is better impressed post-axially. The assignment of these pygidia to *Poronileus* is tentative in the absence of punctate prosopon. They differ from each other in the width (tr.) of the axis relative to the pygidial width, the axial length (sag.) relative to the pygidial length, and the rate of taper of the axis.

Family Raphiophoridae Angelin, 1854
Genus *Ampyx* Dalman, 1827

Type species.—*Asaphus* (*Ampyx*) *nasuta* Dalman, 1827, p. 252, by monotypy, from Sweden.

Ampyx cf. *A. compactus* Ross, 1967
Figure 10.1–10.8

cf. 1967 *Ampyx compactus* Ross, p. D21, pl. 7, figs. 8–16.

Material and occurrence.—Total of 18 cranidia and two pygidia from the Ibexian Ninemile Formation in WCN-F25-40 (13-1-0, plus two articulated carapaces) and WCN-67 (5-1-0).

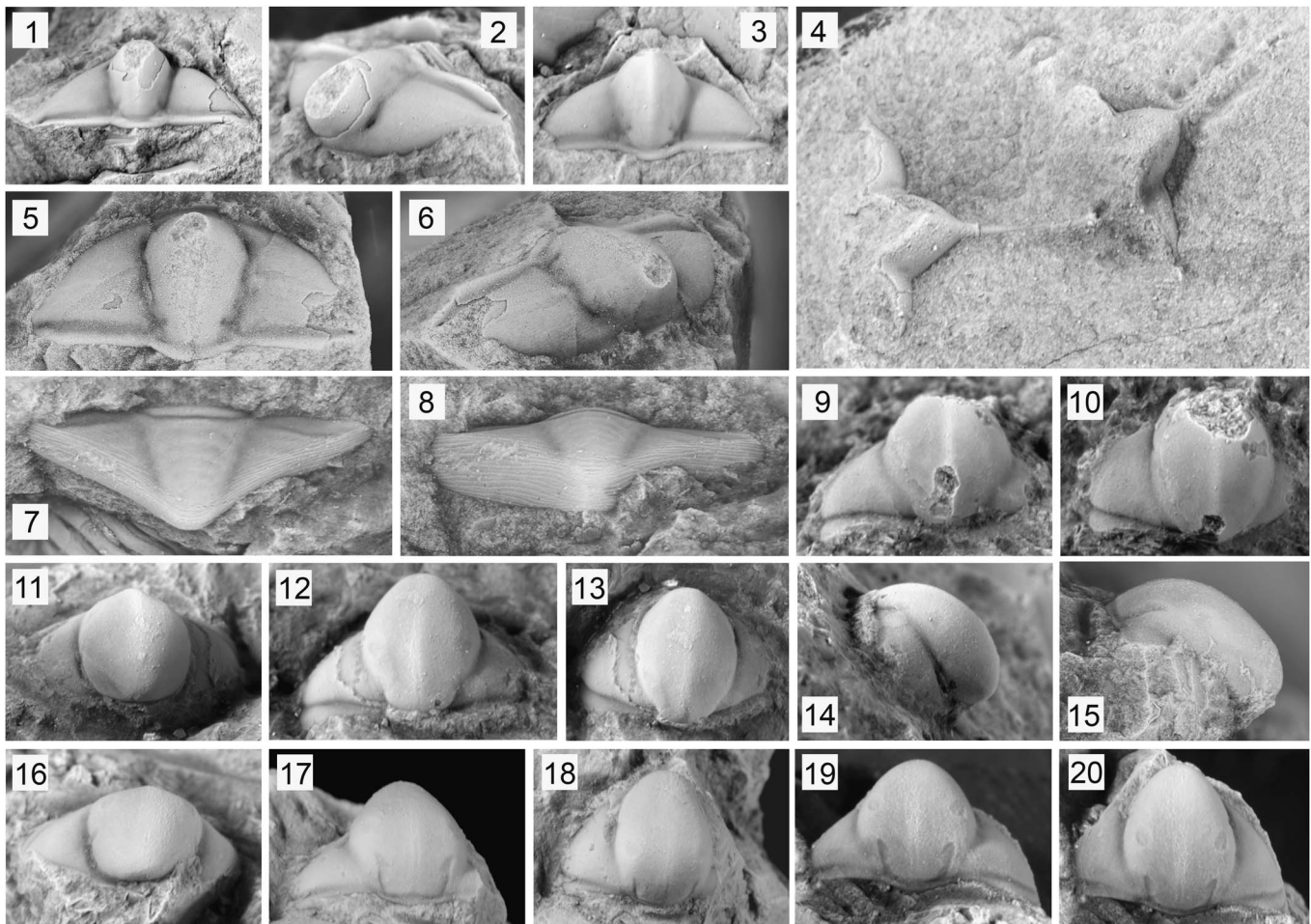


Figure 10. Raphiophoridae Angelin, 1854. (1–8) *Ampyx* cf. *A. compactus* Ross, 1967, all from the Ninemile Formation, (1–2) palpebral ($\times 3.9$) and anterior oblique ($\times 6.2$) views of testate cranidium, WCN-67, CM 59032; (3) palpebral view ($\times 6.1$) of partially exfoliated cranidium, WCN-67, CM 59033; (4) oblique view ($\times 4.7$) of 2 corroded cranidia that shows the extent of the glabella spine, WCN-F25-40, CM 59034; (5, 6) palpebral and anterior oblique views ($\times 5.8$) of testate cranidium, WCN-F25-40, CM 59035; (7, 8) dorsal ($\times 8.9$) and posterior ($\times 8.4$) views of testate pygidium, WCN-67, CM 59036. (9–14) *Ampyxoides* cf. *A. occipitalis* Dean, 1973, from Ninemile Formation; (9–10) dorsal, dorsal oblique views ($\times 6.3$) of partially exfoliated, fragmentary cranidium, WCN-159, CM 59040; (11–14) anterior ($\times 6.3$), dorsal ($\times 4.5$), dorsal oblique ($\times 4.8$), and lateral ($\times 5.5$) views of largely exfoliated cranidium, WCN-159, CM 59039. (15–20) *Ampyxoides*? sp. 1, from Antelope Valley Limestone, WCN-177. (15–18) lateral ($\times 7.2$), anterior ($\times 6.2$), dorsal ($\times 4.6$), and dorsal oblique ($\times 5.3$) views of partially exfoliated cranidium, CM 59037; (19, 20) dorsal and dorsal oblique views ($\times 6.4$) of exfoliated cranidium, Antelope Valley Limestone, CM 59038.

Remarks.—The material recovered from the Ninemile Formation compares with *Ampyx compactus* Ross (1967) in the shape of the glabella, the S1 lateral glabellar furrows, and the inclined posterior border of the cranidium. The occipital ring and posterior of the glabella, however, are wider (tr.) than in the specimens illustrated by Ross. Further, while the overall shape of the pygidium and the convexity of the pygidial margin are consistent, the Ninemile Formation pygidia are somewhat more elongate and have axial and ring furrows that are more well impressed.

Genus *Ampyxoides* Whittington, 1965

Type species.—*Ampyx semicostatus* Billings, 1865, by original designation, from the Table Head Group of Newfoundland, Canada.

Remarks.—Two moderately common species from the upper Ninemile Formation and lower Antelope Valley Limestone are questionably assigned to *Ampyxoides* following Fortey and Droser (1999, p. 195). The diagnosis of *Ampyxoides* (Whittington, 1965, p. 319), however, notes the presence of a glabellar spine that the Nevada specimens lack. Additionally, the Nevada taxa achieve their maximum glabellar width at or posterior to the glabellar mid-length. Both conditions appear uncommon among the Raphiophoridae and these species may better represent a new genus. In the absence of an assigned pygidium, however, they are retained with uncertainty within *Ampyxoides*.

Ampyxoides? cf. *A. occipitalis* Fortey and Droser, 1999
Figure 10.9–10.14

1999 *Ampyxoides* cf. *occipitalis* Dean, 1973; Fortey and Droser, p. 195, fig. 8.1–8.5.

Material and occurrence.—Total of 10 cranidia. Present in the Ninemile Formation in WCN-159 (6-0-0) and WCN-163.5 (1-0-0), and in the Antelope Valley Limestone in WCN-174 (2-0-0) and WCN-177 (1-0-0). This material extends the range of the species, previously known from the lower Antelope Valley Limestone (Fortey and Droser, 1999), downward into the upper Ninemile Formation.

Remarks.—Fortey and Droser (1999) first illustrated this species from the basal Antelope Valley Limestone at the Whiterock Canyon Narrows and compared it to known species of *Ampyxoides*. The Ninemile Formation specimens appear conspecific with those illustrated by Fortey and Droser (1999) in lacking a glabellar spine, exhibiting a weakly keeled glabella that is widest slightly posterior to its mid-length, the posterior width (tr.) of the glabella at the occipital furrow is slightly less than half the maximum pygidial width, axial furrows that are slightly adaxially convex posteriorly, and very faint S1, S2 furrows, and a pit-like S3 furrow present anterior to the glabellar mid-length.

The cranidium of *Ampyxoides* cf. *occipitalis* compares broadly to that of *Ampyxoides occipitalis* Dean (1973, p. 4–6, pl. 1, figs. 7–9, 15, 16) in having a glabella that is constricted

posteriorly. The glabella of *A. occipitalis*, however, bears a glabellar spine, is more angular anteriorly, stands well above the occipital lobe in lateral view, and is proportionately narrower medially (tr.) compared to its length. Further, the fixigenae are larger (exsag., tr.) in *A. occipitalis*. Were additional sclerites of the Nevada material available, the introduction of a new species name would appear appropriate.

Ampyxoides? species 1
Figure 10.15–10.20

Material and occurrence.—Total of eight cranidia. Present in the Whiterockian Antelope Valley Limestone in WCN-176 (2-0-0), WCN-177 (3-0-0), and WCN-178 (3-0-0).

Remarks.—A species of *Ampyxoides?* with a faintly keeled glabella that is broad and ovate in outline and with elongate S1 glabellar furrows that extend anteriorly on exfoliated specimens. *Ampyxoides?* sp. 1 differs from *Ampyxoides* cf. *A. occipitalis* (Fortey and Droser, 1999, p. 195, figs. 8.1–8.5) in the outline of the glabella that is broader posteriorly, the less well-developed keel, and the elongate S1 furrow. *Ampyxoides?* sp. 1 differs from the type species, *Ampyxoides semicostatus* (Billings, 1865; Whittington, 1965, p. 319–321, pl. 12, figs. 13–20, pl. 13, figs. 1–10, 12) in lacking a glabellar spine, in the more ovate shape of the glabella, and elongate S1 furrows. *Ampyxoides inermis* Fortey (1975, p. 74–76, pl. 30, figs. 10–15, 1980, pl. 17, fig. 9) exhibits a small glabellar spine, fixigenae that are more broad (tr.), posterior border furrows that are only faintly impressed, and has axial furrows that are curved abaxially rather than adaxially from the occipital furrow to the glabellar mid-length. *Ampyxoides occipitalis* Dean (1973, p. 4–6, pl. 1, figs. 7–9, 13, 15, 16) possesses a glabellar spine, lacks a preglabellar area, and has a glabella that is inflated posteriorly to stand above the occipital ring in lateral view.

Order Corynexochida Kobayashi, 1935
Family Illaenidae Hawle and Corda, 1847
Genus *Illaeus* Dalman, 1827

Type species.—*Entomostracites crassicauda* Wahlenberg, 1821, subsequent designation by Miller (1889), from the Crassicauda Limestone of Sweden.

Illaeus welchi new species
Fig. 11.1–11.11

1972 *Illaeus* sp. b Ross, p. 32, pl. 13, figs. 14–19, pl. 14, figs. 1–6.

1972 *Illaeus* sp. d Ross, p. 33, pl. 14, figs. 13–15.

Type specimens.—Holotype, enrolled carapace, CM 59041, Ibexian Ninemile Formation at the Whiterock Canyon Narrows, Nevada. Paratypes, CM 59042–46.

Diagnosis.—*Illaeus* with angular axial furrows, narrow, cord-like anterior border, and anterior branch of the facial sutures that are subparallel or weakly convergent to anterior margin. Pygidium semi-elliptical in outline, pygidial width

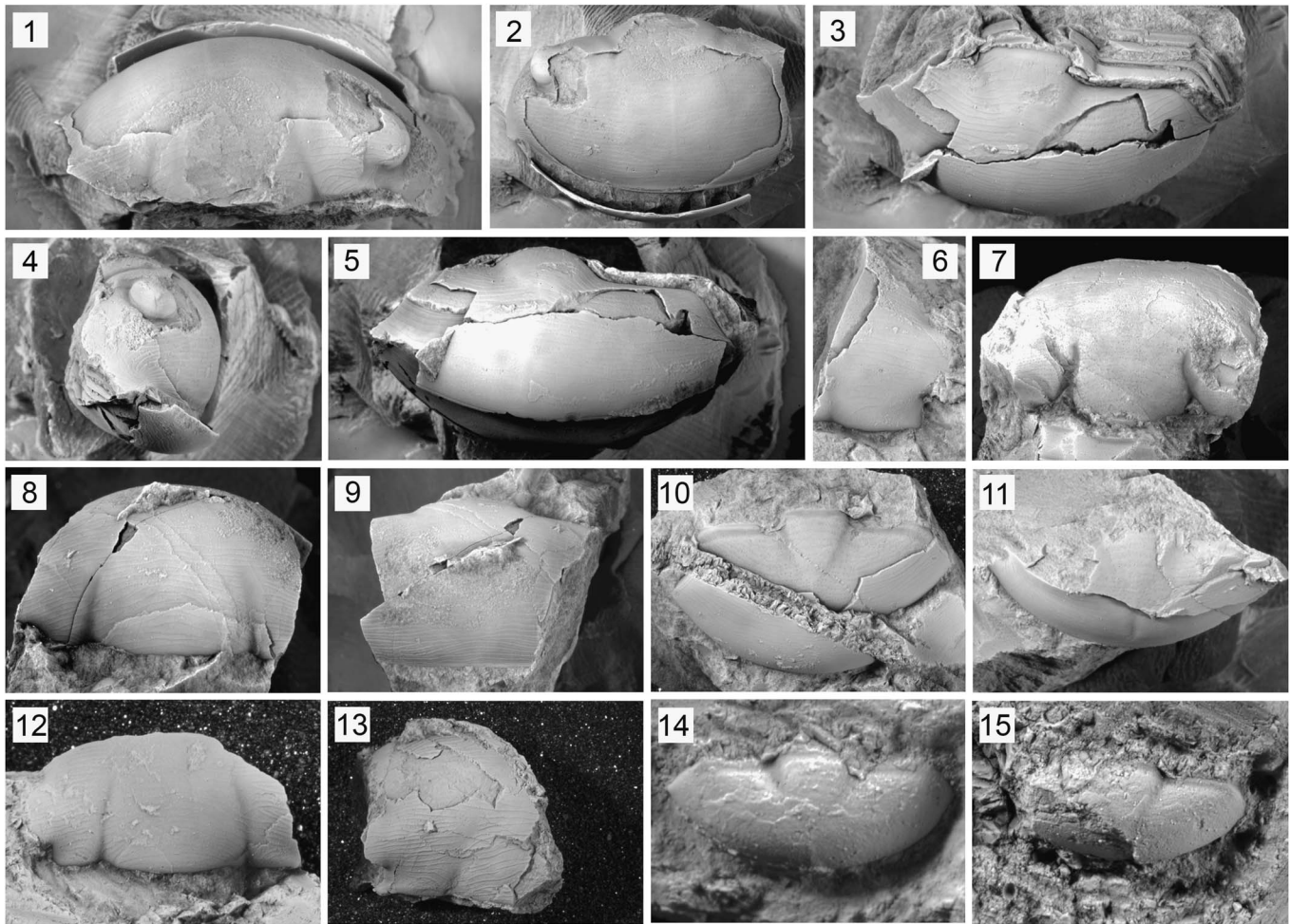


Figure 11. *Illaeus* Dalman, 1827. (1–11) *Illaeus welchi* n. sp., all from Ninemile Formation, (1–5) palpebral ($\times 1.9$), anterior cranial ($\times 1.7$), dorsal pygidial ($\times 1.9$), lateral ($\times 1.7$), and posterior pygidial ($\times 1.9$) views of partially exfoliated, holotype carapace, WCN-145, CM 59041; (6) palpebral view ($\times 2.2$) of testate, fragmentary paratype cranidium, WCN-132, CM 59042; (7) palpebral view ($\times 1.9$) of exfoliated, paratype cranidium, WCN-145, CM 59043; (8, 9) palpebral and anterior views ($\times 2.7$) of testate, paratype cranidium, WCN-146, CM 59044; (10) dorsal view ($\times 1.8$) of largely exfoliated, paratype pygidium, WCN-145, CM 59045; (11) dorsal view ($\times 2.0$) of partially exfoliated, paratype pygidium exhibiting doublure, WCN-145, CM 59046. (12–15) *Illaeus* cf. *I. auriculatus* Ross, 1972, all from Antelope Valley Limestone, (12) palpebral view ($\times 3.2$) of testate cranidium, WCN-176, CM 59047; (13) palpebral view ($\times 1.7$) of fragmentary, testate cranidium, WCN-178, CM 59048; (14) dorsal view ($\times 4.8$) of exfoliated pygidium, WCN-190, CM 59049; (15) dorsal view ($\times 4.6$) of fragmentary, exfoliated pygidium, WCN-176, CM 59050.

equal to twice pygidial length measured dorsally, triangular axis with length equal to maximum axial width.

Description.—Cranidium large, up to 1.5 cm in palpebral view, tall, up to 1.5 cm in anterior view, subrectangular in outline; strongly convex (sag.) to overhang anterior margin, passes through $\sim 270^\circ$ of arc in lateral view. Axial furrows broad, moderately impressed, subparallel at posterior margin; bent adaxially at 15° angle opposite posterior end of palpebral lobes; bent at anterior end of palpebral lobes back to subparallel orientation, shallowed until obsolete before overhang in anterior area. Glabella broad posteriorly, greater than half cranial width (tr.), narrowed to $9/10$ of basal glabellar width at anterior end of palpebral lobes. Preglabellar furrow not defined. Anterior border cord-like, mildly elevated above preglabellar area; anterior border furrow slightly impressed, of uniform depth laterally. Palpebral lobes simple, slightly declined from axial furrows. Anterior branch of facial suture subparallel to slightly convergent to anterior border; posterior branch of facial suture

subperpendicular to posterior margin. Prosopon on testate specimens of fine terrace lines across entire cranidium except for smooth spot in the axial furrows at the anterior end of the palpebral lobes, lines more densely packed on anterior area, most densely packed on anterior border, scattered fine pits present on glabella, posterior and palpebral areas. Exfoliated surfaces with gentle rugae reflecting terrace lines, pits aligned in recesses of rugae, smooth spot in axial furrows present, faint occipital node present.

Pygidium large, up to 2.0 cm in length measured dorsally; semi-elliptical in outline, twice as broad as long measured in dorsal view; moderately convex (tr., sag.) with distal margin slightly overturned. Axis long, $6/10$ pygidial length measured in dorsal view, triangular in outline on exfoliated surfaces with axial length equal to maximum axial width, poorly defined posteriorly on testate specimens; slightly convex (tr.). Axial furrows broad, faintly impressed, incomplete posteriorly on testate surfaces; weakly impressed, meet along axis on exfoliated surfaces. Articulating furrow moderately impressed.

Pleural fields undivided except for single intrapleural furrow defining short anterior band; slightly convex (exsag.), strongly declined becoming overturned marginally. Long (sag.), slightly concave doubleure, longer axially than laterally, with broad fold axially.

Etymology.—In honor of James R. Welch, in recognition of the support for this research by the American Association of Paleontological Suppliers under their James R. Welch Scholarship.

Material and occurrence.—Total of 14 cranidia, six pygidia, one fragmentary librigena, and one enrolled carapace. Present in the Whiterockian Ninemile Formation in WCN-132 (5-2-0), WCN-134 (4-2-0), WCN-145 (1-1-0, plus one enrolled carapace), WCN-146 (2-1-1), and WCN-159 (2-0-0). Previously reported from the Antelope Valley Limestone at Meiklejohn Peak, Nevada (Ross, 1972).

Remarks.—*Iliaenus welchi* n. sp. is based upon an enrolled carapace that allowed for the certain association of cranidia and librigenae illustrated by Ross (1972) as *Iliaenus* sp. b with pygidia illustrated as *Iliaenus* sp. d.

Ross (1972, p. 32) suggested that *Iliaenus* sp. ind. 2 of Whittington (1963, p. 73–74, pl. 19, figs. 5, 6, 8, 9) bore a close resemblance to *Iliaenus* sp. b (= *Iliaenus welchi* n. sp.). *Iliaenus* sp. ind. 2, however, has divergent axial furrows adjacent to the posterior cranidial margin and it is excluded from *I. welchi*.

Iliaenus oscitatus Fortey (1980, p. 60–62, pl. 10, figs. 1–13) is similar to *Iliaenus welchi* n. sp. in the angular course of its cranidial axial furrows, raised anterior border, and subparallel anterior facial sutures. *Iliaenus oscitatus*, however, has prominent pits and a more greatly overhung frontal area on the cranidium. The pygidium of *I. oscitatus* also is proportionally longer in dorsal view with concave, rather than straight, axial furrows.

Iliaenus cf. *I. auriculatus* Ross, 1972
Figure 11.12–11.15

1972 *Iliaenus* cf. *I. auriculatus* Ross, p. 32, pl. 12, figs. 19–26, pl. 13, figs. 1–13, pl. 14, figs. 23–25.

1999 *Iliaenus* cf. *I. auriculatus*; Fortey and Droser, p. 192, fig. 6.1–6.11.

Material and occurrence.—Total of five cranidia, five pygidia, and one librigena. Present in the Antelope Valley Limestone in WCN-176 (4-2-0), WCN-177 (1-0-0), WCN-178 (1-1-1), and WCN-190 (0-2-0). Previously documented from the Antelope Valley Limestone by Ross (1972) and Fortey and Droser (1999).

Remarks.—*Iliaenus auriculatus* Ross (1972) was based upon a silicified collection of small specimens from the Antelope Valley Limestone at Pyramid Peak, California. Ross later (1972) considered “crack out” material from Meiklejohn Peak, Nevada, as comparable to *I. auriculatus*. The evenly curved, weakly impressed axial furrows on the cranidium that terminate at the anterior end of the palpebral lobes are consistent with these latter specimens. Fortey and Droser (1999) provided a good

discussion of larger *Iliaenus* cf. *I. auriculatus* specimens from mechanically prepared specimens and comparisons to other *Iliaenus* species.

Family Styginidae Vodges, 1890
Genus *Perischoclonus* Raymond, 1925

Type species.—*Perischoclonus capitalis* Raymond, 1925, by original designation, from the Shallow Bay Formation of Newfoundland, Canada.

Perischoclonus sp.
Figure 12.8

Remarks.—A single transverse pygidium from the Ninemile Formation, WCN-146, is assigned to the genus *Perischoclonus*. This pygidium exhibits a long axis of 6+ rings, moderately impressed pleural furrows that extend onto the border, a slightly concave border defined by a weakly impressed border furrow,

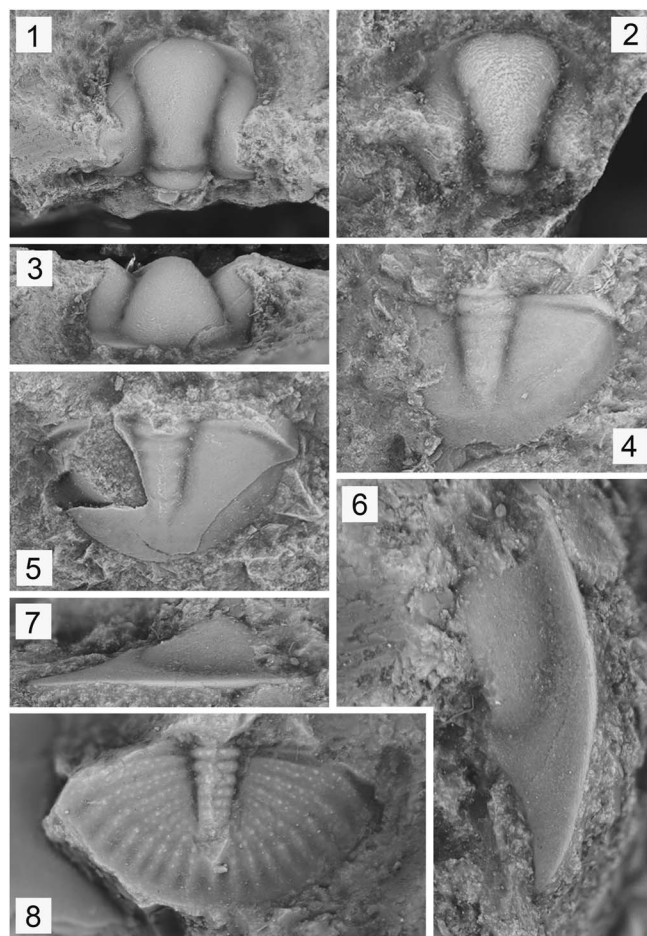


Figure 12. Styginidae Vodges, 1890. (1–7) *Raymondaspis* cf. *R. vespertina* Ross, 1967, (1, 3) palpebral ($\times 6.7$) and anterior ($\times 7.5$) views of testate cranidium, Antelope Valley Limestone, WCN-174, CM 59051; (2) palpebral view ($\times 8.1$) of testate cranidium, Ninemile Formation, WCN-159, CM 59052; (4) dorsal view ($\times 6.9$) of testate pygidium, Ninemile Formation, WCN-159, CM 59053; (5) dorsal view ($\times 6.9$) of testate pygidium, Ninemile Formation, WCN-159, CM 59054; (6, 7) lateral ($\times 9.5$) and dorsal ($\times 13.2$) views of testate librigena, Ninemile Formation, WCN-159, CM 59055. (8) *Perischoclonus* sp., dorsal view ($\times 15.0$) of testate pygidium, Ninemile Formation, WCN-146, CM 59056.

and granulose prosopon. In these characters, the pygidium is consistent with the type species, *Perischoclonus capitalis* Raymond, 1925 (see Whittington, 1963, p. 80–84, pl. 22, figs. 1–13, pl. 35, figs. 10, 11, pl. 36, figs. 5, 7, 8). The Nevada pygidium differs from the type in being more transverse, having a more distinct border furrow, and pleural furrows that are better impressed adaxially. Granules appear in two lines on the anterior three pleural ribs, suggesting the presence of faintly impressed interpleural furrows anteriorly. Ross (1970, p. 89, pl. 17, fig. 20) assigned a poorly preserved cranidium from the Antelope Valley Limestone at Ikes Canyon to *Perischoclonus*, noting the presence of a Bertillion pattern on the glabella rather than granules.

Genus *Raymondaspis* Pribyl in Prantl and Pribyl, 1948

Type species.—*Holometopus limbatus* Angelin, 1854, by original designation, from the Komstad Limestone of Sweden.

Remarks.—Neilsen (1995) chose to treat *Turgicephalus* Fortey (1980) as a subgenus of *Raymondaspis*. We prefer retain the two taxa as separate at the generic rank.

Raymondaspis cf. *R. vespertina* Ross, 1967
Figure 12.1–12.7

- non 1967 *Raymondaspis vespertinus* Ross, p. D15, pl. 4, figs. 16–20.
non 1980 *Raymondaspis vespertina*; Fortey, p. 50, pl. 6, figs. 1–8, 11.
cf. 1999 *Raymondaspis vespertina*; Fortey and Droser, p. 193, fig. 5.9–5.11.

Material and occurrence.—Total of 29 cranidia, 17 pygidia, and seven librigenae. Present in the Whiterockian Ninemile Formation in WCN-132 (2-1-0), WCN-145 (7-0-0), WCN-146 (3-2-0), WCN-159 (6-8-7), and WCN-163.5 (5-0-0). Present in the Antelope Valley Limestone in collections WCN-172 (0-1-0) and WCN-174 (6-5-1). These collections extend the range of the species previously documented from the Antelope Valley Limestone (Fortey and Droser, 1999) downward into the Ninemile Formation.

Remarks.—The testate specimens recovered and illustrated from the Ninemile Formation conform to those previously illustrated from the Antelope Valley Limestone at Whiterock Canyon (Fortey and Droser, 1999) in their prosopon of fine terrace lines, the small occipital node, the small fossula in the axial furrows, and moderately long (exsag.) preocular portion of the anterior border. The pygidia in each case exhibit axial furrows that are slightly curved so that the axis tapers markedly. The recovery of conspecific specimens from the Ninemile Formation extends the documented range of *Raymondaspis* cf. *R. vespertina* at the Whiterock Canyon Narrows.

Raymondaspis cf. *R. vespertina* differs in its cranidia from the silicified type material from Pyramid Peak, California, (Ross, 1967) by possessing a glabella that is proportionately narrower at its maximum width and in having a more clearly defined anterior border, particularly at the anterolateral

corner. The Nevada pygidia differ from the type material in having an evenly curved posterior margin, whereas the type material has a slight angulation axially, and a proportionately longer axis.

Cranidia from Spitzbergen assigned to *Raymondaspis vespertina* by Fortey (1980) have better impressed lateral glabellar furrows than in *R. cf. R. vespertina*, although this may reflect the larger size of the illustrated Spitzbergen cranidia. Further, the length of the anterior border (exsag.) at the anterolateral corner appears longer in the Spitzbergen material. The Spitzbergen pygidia possess axes that are slightly more than half the pygidial length while those from Nevada approach three-quarters of the pygidial length. The Spitzbergen pygidia are weakly furrowed on the pleural fields while the Nevada specimens appear unfurrowed. Finally, although the librigena illustrated from Nevada (Fig. 12.6, 12.7) is fragmentary, the genal spine appears less rapidly tapering and longer than those from Spitzbergen.

Order Phacopida Salter, 1864
Family Calymenidae Burmeister, 1843
Genus *Protocalymene* Ross, 1967

Type species.—*Protocalymene mcallisteri* Ross, 1967, p. D27, by original designation, from the Antelope Valley Limestone of Nevada and California.

Protocalymene sp.
Figure 13.6

Remarks.—A single fragmentary pygidium from WCN-169 in the uppermost Ninemile Formation is assigned to *Protocalymene* sp. This pygidium exhibits a slightly convex (tr.) axis of four rings with an inflated terminal axial piece (sag), ring furrows that are deeply incised laterally, interpleural and pleural furrows that cross to a poorly defined border furrow, a distinct arch in posterior view, and a granulose prosopon that is more dense on the distal pleural fields than proximally. While these characters are reminiscent of *Protocalymene mcallisteri* Ross (1967, p. D27–D28, pl. 9, figs. 1–28), the specimen is too fragmentary to permit definitive assignment.

Family Cheiruridae Salter, 1864
Cheiruridae indet.
Figure 13.9, 13.10

Remarks.—A single fragmentary cranidium was recovered from the Antelope Valley Limestone, WCN-190. It is a finely granulose glabella, bearing three pairs of faint lateral glabellar furrows, that is strongly convex (sag.) to appear overhung in lateral view. The glabella is reminiscent of specimens of *Kawina ? unicornica* Hintze (1953, pl. 28, p. 179) in the finely granulose prosopon, lateral glabellar furrows, and prominent size of the glabella. Although there is insufficient material to assign the specimen to genus, it does seem to conform to aspects of other cheirurids.

Family Encrinuridae Angelin, 1854
Genus *Cybelurus* Levitsky, 1962

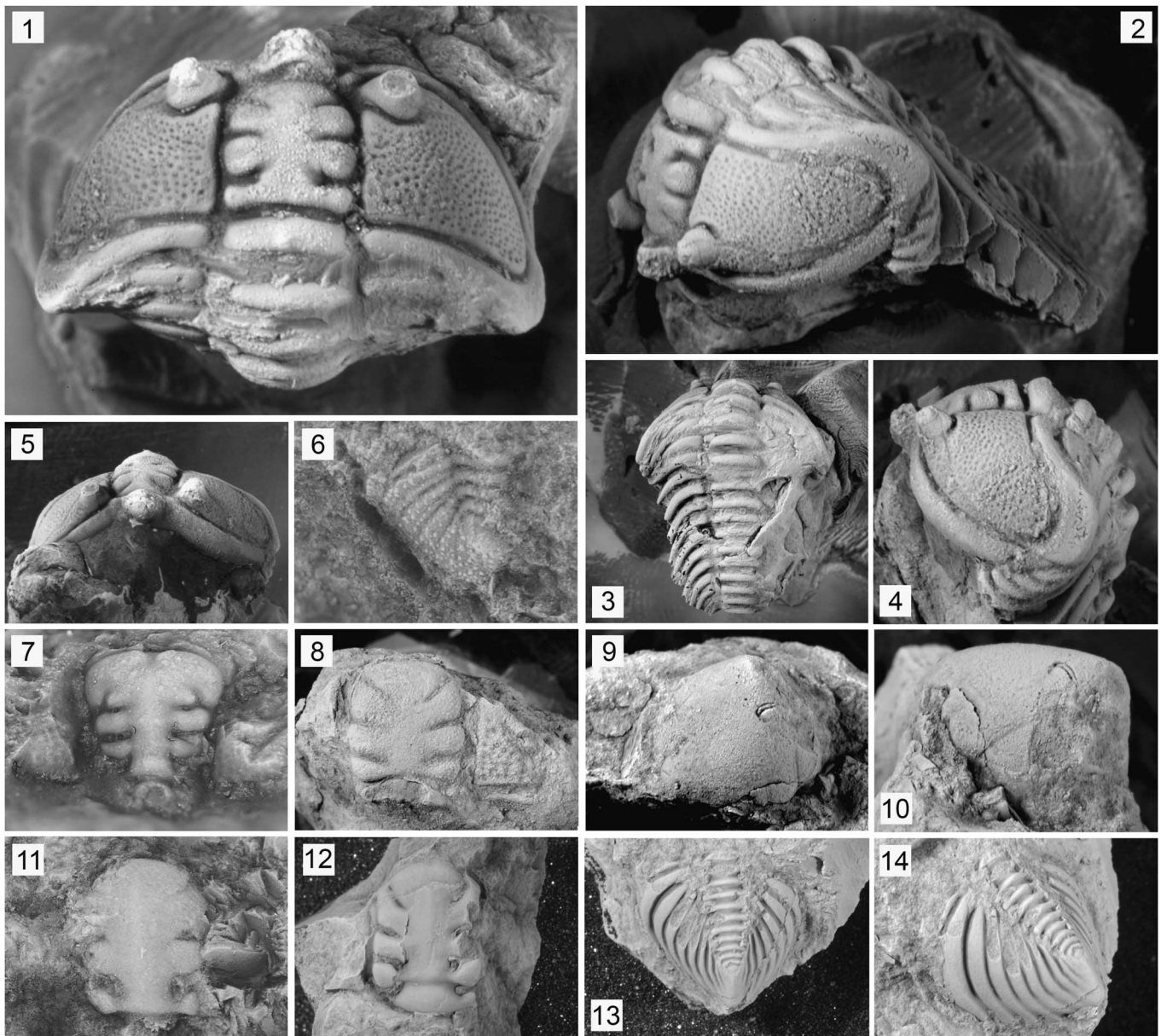


Figure 13. Order Phacopida Salter, 1864. (1–5) *Pseudocybele* sp., palpebral ($\times 4.5$), anterior oblique ($\times 4.5$), dorsal ($\times 1.7$), lateral oblique ($\times 2.4$), and anterior ($\times 2.4$), views of testate carapace, Ninemile Formation, WCN-F25–40, CM 59057. (6) *Protocalymene* sp., dorsal view ($\times 10.5$) of small, fragmentary, testate pygidium, Ninemile Formation, WCN-169, CM 59058. (7) *Cybelurus* sp., palpebral view ($\times 7.0$) of fragmentary, testate cranidium, Ninemile Formation, WCN-146, CM 59059. (8) *Pseudomera arachnopyge* Fortey and Droser, 1996, palpebral view ($\times 1.8$) of large, fragmentary, partially exfoliated cranidium, Antelope Valley Limestone, WCN-190, CM 59060. (9, 10) Cheiruridae indet., palpebral and lateral views ($\times 3.4$) of fragmentary, testate cranidium, Antelope Valley Limestone, WCN-190, CM 59061. (11–14) *Ectenonotus* spp., from Ninemile Formation, (11) palpebral view ($\times 8.3$) of fragmentary, exfoliated cranidium, WCN-159, CM 59062; (12) palpebral view ($\times 1.8$) of fragmentary, exfoliated cranidium, WCN-149, CM 59063; (13, 14) dorsal and lateral oblique views ($\times 2.5$) of largely exfoliated pygidium, WCN-145, CM 59064.

Type species.—*Cybelurus planus* Levitsky, 1962, by original designation, from the Bugryshikhinsk Beds, Sayan Altay, Russia.

Cybelurus sp.
Figure 13.7

Material and occurrence.—A total of three cranidia from the Whiterockian Ninemile Formation in WCN-134 (1-0-0) and WCN-146 (2-0-0).

Remarks.—These cranidia are assigned to *Cybelurus* on the basis of their anteriorly expanding glabella, median glabellar furrow,

and well impressed lateral glabellar furrows. The fragmentary specimens recovered from the Ninemile Formation are broadly similar to *Cybelurus halo* Fortey (1980, p. 95–98, pl. 22, figs. 1–15, pl. 25, fig. 12) from Spitzbergen, although preservation prevents a definitive identification. The Nevada material possesses a glabella that is moderately broad (tr.) posteriorly and is broadly rounded in the anteriolateral corners; further the S3 and S4 lateral glabellar furrows intersect at a discrete distance from the axial furrows. While Fortey and Droser (1999) have identified *C. halo* from the Antelope Valley Limestone from Little Rawhide Mountain, Nevada, this is the first recovery of *Cybelurus*

from the Whiterock Canyon Narrows. *Cybelurus brutoni* Fortey (1980, p. 95, 98, pl. 23, figs. 1–6) exhibits a more posteriorly constricted glabella with S3 and S4 that intersect at the axial furrow. The Ninemile Formation specimens lack the separate S4 lateral glabellar furrow seen on *Cybelurus occidentalis* Dean (1973, p. 10–13, pl. 2, figs. 2, 3, 5–10, pl. 3, figs. 1, 2, 4).

Family Pliomeridae Raymond, 1913

Genus *Ectenonotus* Raymond, 1920

Type species.—*Amphion westoni* Billings, 1865, p. 321–322, by original designation, from the Mystic Conglomerate of Quebec, Canada.

Remarks.—Raymond (1920) erected *Ectenonotus* to include those pliomerids with 12–15 axial rings on the pygidium. Whittington (1961, p. 915–916, pl. 99, text-fig. 4, figs. 1–4, 6–9) selected a lectotype, described and reillustrated the type species, *Ectenonotus westoni*. Whittington (1961, p. 916–917, pl. 99, figs. 5, 10–15), and illustrated specimens that he recovered from the Whiterock Canyon Narrows, referring them to *Ectenonotus* cf. *westoni*. He separated *E.* cf. *westoni* from the type species without diagnosing specific differences. Subsequently, Ross (1967, p. D24–D25) erected *Ectenonotus whittingtoni* based upon specimens recovered from the Antelope Valley Limestone and included Whittington's *Ectenonotus* cf. *westoni* within it.

Ectenonotus spp.

Figure 13.11–13.14

Material and occurrence.—A total of two cranidia, three pygidia, and two librigenae from the Whiterockian Ninemile Formation shale in WCN-146 (1-1-0), WCN-159 (1-1-1), and WCN-163.5 (1-0-0), and from the Antelope Valley Limestone in WCN-172 (0-1-0) and WCN-174 (0-1-1) are treated as *Ectenonotus* spp.

Remarks.—The incomplete cranidia (Fig. 13.11, 13.12) from the Ninemile Formation exhibit long and curving 3S lateral glabellar furrows, anteriorly rounded frontal glabellar lobes, and elongate glabella. They differ from the species *Ectenonotus whittingtoni* Ross (1967, p. D24–D25, pl. 7, figs. 33, 34, pl. 8, figs. 1–22) that exhibit short, straight 3S lateral glabellar furrows and glabellas that are proportionately wider.

The illustrated pygidium (Fig. 13.13, 13.14) conforms in relative proportions, general shape, and composition of the axis, and the shape and orientation of the interpleural furrow to *Ectenonotus whittingtoni*. The post-axial portion of the pygidium, however, is longer in dorsal view, more steeply declined, and more rounded in posterior view than seen in *E. whittingtoni*.

Genus *Pseudocybele* Ross, 1951

Type species.—*Pseudocybele nasuta* Ross, 1951, p. 137–138, by original designation, from the Garden City Formation of Utah.

Pseudocybele sp.

Figure 13.1–13.5

Remarks.—Two articulated individuals and an articulated thorax were recovered from the Ibexian Ninemile Formation from WCN-F40. The individual illustrated here conforms in its cranial details to *Pseudocybele* in the shape of the anterior border and the anterior position of the palpebral lobes. The glabella in this specimen is markedly parallel-sided and bluntly rounded anteriorly. Anteriorly, the axial furrows on *Pseudocybele nasuta* Ross (1951, p. 138–140, pl. 33, figs. 1–14, pl. 34, figs. 13–17, 21–27; = “*Pseudocybele nasuta*” in Adrain et al., 2009, fig. 21A, 21D) and *P. paranasuta* McAdams and Adrain (2010, p. 25–37, figs. 3–8) converge so that the anterior lobe to the glabella appears more tapered. *Pseudocybele altinasuta* Hintze (1953, p. 216, pl. 24, figs. 1, 2) also exhibits a parallel-sided glabella, which, however, is markedly more narrow.

Genus *Pseudomera* Holliday, 1942

Type species.—*Amphion barrandei* Billings, 1865, p. 288–289, by original designation, from Newfoundland, Canada.

Pseudomera arachnopyge Fortey and Droser, 1996

Figure 13.8

1996 *Pseudomera arachnopyge* Fortey and Droser, p. 96, fig. 18.1–18.8.

Holotype.—Pygidium, United States National Museum (USNM) 481385, Whiterockian Juab Formation from Ibex, Nevada, section J of Hintze (1953).

Occurrence.—A single cranidium from the Antelope Valley Limestone was recovered from WCN-190. *Pseudomera arachnopyge* has been reported from the *Psephosthenaspis pseudobathyrurus* Zone of Fortey and Droser, 1996 (= *Orthis subalata* Zone [Zone L] of Hintze, 1953, or the *Paralenorthis-Orthidiella* Zone of Ross et al., 1997) from the uppermost Wah Wah Limestone Formation and lower Juab Formation of the Ibex region and the Garden City Formation of Utah, (Fortey and Droser, 1996), as well as, without illustration, from the Antelope Valley Limestone at the Whiterock Canyon Narrows (Fortey and Droser, 1999, fig. 2).

Remarks.—The fragmentary cranidium compares well with *Pseudomera arachnopyge* Fortey and Droser (1996) in the subrectangular and bluntly truncate outline of the glabella, the position of the palpebral lobes, and the position and orientation of the S3 lateral glabellar furrows.

Order Proetida Fortey and Owens, 1975

Family Bathyruridae Walcott, 1886

Genus *Acidiphorus* Raymond, 1925

Type species.—*Acidiphorus spinifer* Raymond, 1925, p. 131, by original designation, from the Head Group, Newfoundland, Canada.

Acidiphorus cf. *A.?* *lineotuberculatus* Fortey and Droser, 1999

Figure 14.1, 14.2

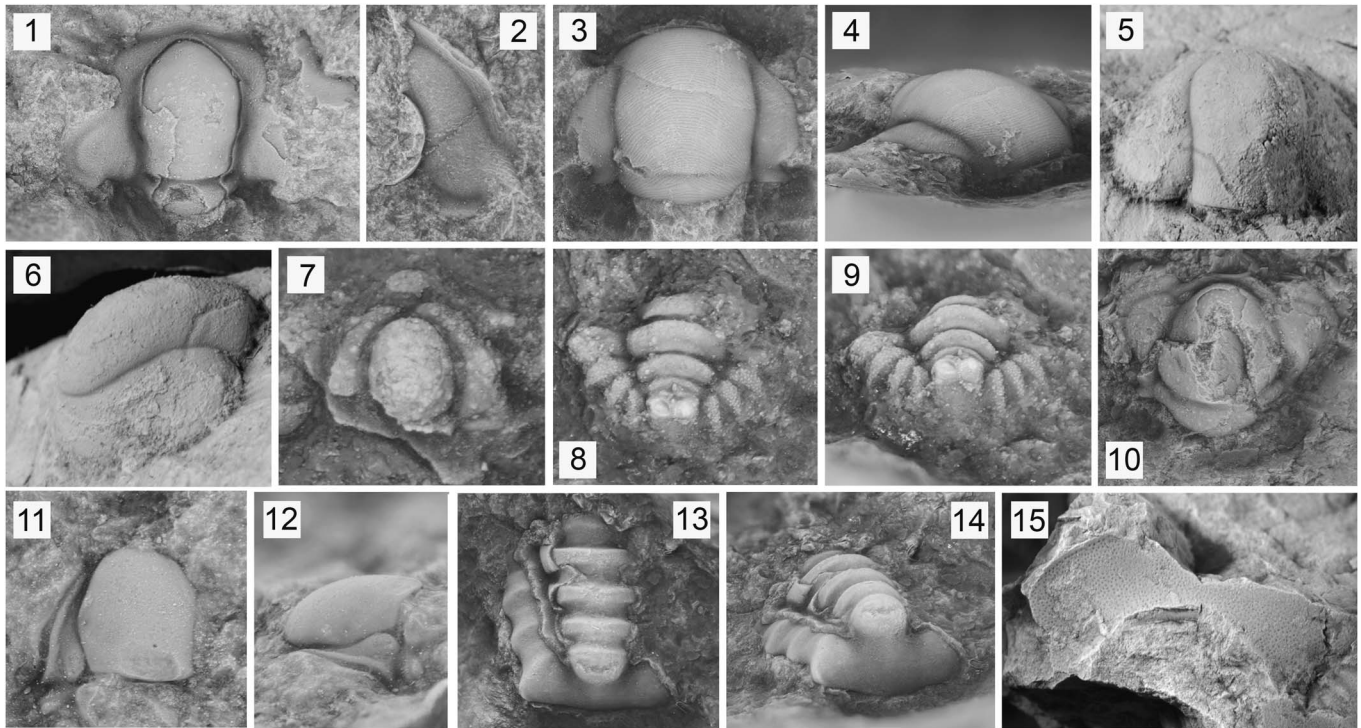


Figure 14. Orders Proetida Fortey and Owens, 1975, and Ptychopariida Swinnerton, 1915. (1, 2) *Acidiphorus?* cf. *A.?* *lineotuberculatus* Fortey and Droser, 1999, from Ninemile Formation, (1) palpebral view ($\times 7.0$) of partially exfoliated cranidium, WCN-132, CM 59065; (2) dorsal view ($\times 5.8$) of testate librigena, collection WCN-132, CM 59066. (3, 4) *Benthamaspis sera* Fortey and Droser, 1999, palpebral and anterior oblique views ($\times 5.3$) of testate cranidium, Ninemile Formation, WCN-144, CM 59067. (5, 6) *Uromystrum* sp. 3 (Ross, 1972), palpebral and lateral views ($\times 3.1$) of corroded cranidium, Ninemile Formation, collected from float, CM 59068. (7–9) *Ischyrotoma* cf. *I. caudanodosa* Ross (1951), from Ninemile Formation, (7) palpebral view ($\times 18.0$) of small, corroded cranidium, WCN-F25-40, CM 59069; (8, 9) dorsal and posterior view ($\times 15.0$) of small, testate pygidium, WCN-F25-40, CM 59070. (10) *Oopsites* sp. (Reed in Gardiner and Reynolds, 1909), palpebral view ($\times 7.8$), crushed cranidium, Ninemile Formation, WCN-113, CM 59071. (11–14) *Carolinites sibiricus* Chugaeva, 1964, (11, 12) palpebral and anterior oblique views ($\times 15.0$) of fragmentary, testate cranidium, Antelope Valley Limestone, WCN-177, CM 59072; (13, 14) dorsal and posterior oblique views ($\times 7.8$) of largely exfoliated pygidium, Ninemile Formation, WCN-143, CM 59073. (15) Harpetidae indet., dorsal view ($\times 2.5$) of fragmentary cephalon, Ninemile Formation, WCN-64, CM 59074.

cf. 1999 *Acidiphorus?* *lineotuberculatus* Fortey and Droser, p. 189, fig. 4.14–4.19.

non 1999 *Acidiphorus?* *lineotuberculatus* Fortey and Droser, fig. 4.20 (= *Pseudoolenoides pogonipensis* Adrain, McAdams, and Karim, 2012).

Holotype.—Cranidium, United States National Museum (USNM) 495715, Whiterockian Antelope Valley Limestone at Whiterock Canyon, Nevada.

Material and occurrence.—Total of 15 cranidia and two librigenae. Present in the Whiterockian Ninemile Formation in WCN-132 (2-0-1), WCN-145 (1-0-0), WCN-146 (1-0-0), WCN-159 (1-0-0), and WCN-163.5 (2-0-0). Present in the Antelope Valley Limestone in WCN-172 (3-0-0), WCN-174 (3-0-1), and WCN-178 (2-0-0). This report extends the known range (Fortey and Droser, 1999) of the taxon downward into the Ninemile Formation.

Remarks.—The small specimens of *Acidiphorus* cf. *A.?* *lineotuberculatus* recovered from the Ninemile Formation conform to the specimens from the overlying Antelope Valley Limestone described by Fortey and Droser (1999) in their prosopon of mixed lines and tubercles. The present cranidia, however, exhibit axial furrows that diverge anteriorly to form a glabella that is markedly more broad and rapidly expanding

anteriorly than in the type cranidia. Additionally, the fragmentary librigenae recovered exhibit a pronounced swelling at the proximal end of the genal spine greater than that seen in *A.?* *lineotuberculatus* itself.

Genus *Benthamaspis* Poulsen, 1946

Oculomagnus Lochman, 1966, p. 541. [Junior subjective synonym; see Fortey, 1979, p. 100]

Type species.—*Benthamaspis problematica* Poulsen, 1946, p. 325–326, by monotypy, from the Nunatami Formation at Cape Stevens, Ellesmere Island.

Benthamaspis sera Fortey and Droser, 1999
Figure 14.3, 14.4

1997 *Benthamaspis* sp. Adrain and Fortey, p. 101, pl. 1, figs. 7–9.

1999 *Benthamaspis sera* Fortey and Droser, p. 189, fig. 4.1–4.13.

Holotype.—Cranidium, United States National Museum (USNM) 495705; Whiterockian Antelope Valley Limestone from Meiklejohn Peak, Nevada.

Material and occurrence.—One cranidium from the Whiterockian Ninemile Formation, WCN-144. Previously

recovered from Meiklejohn Peak, Nevada (Fortey and Droser, 1999) and the Tourmakeady Beds of Ireland (Adrain and Fortey, 1997).

Remarks.—The impression of the axial furrows, shape of the preocular area, proportions of the palpebral lobes, and glabellar convexity of the small specimen illustrated from the Whiterock Canyon Narrows conform well to the specimens from Meiklejohn Peak, Nevada (Fortey and Droser, 1999). *Benthamspis diminutiva* Hintze (1953, p. 142–143, pl. 13, figs. 9–12; Dean, 1989, p. 28–29, pl. 20, figs. 9–13; Fortey and Droser, 1999, fig. 21O, 21S), known from Zone J (= the “*Pseudocybele nasuta*” Zone of Adrain et al., 2009), differs in the breadth of the glabella and the abaxially curved axial furrows.

Genus *Uromystrum* Whittington, 1953

Type species.—*Bathyurellus validus* Billings, 1865, p. 268, by original designation, from the Table Head Group of Newfoundland, Canada.

Uromystrum sp. 3 (Ross, 1972)
Figure 14.5, 14.6

1972 *Bathyurellus* sp. 3 Ross, p. 35, pl. 15, figs. 17–19.

Material and occurrence.—A single cranidium recovered from an unrecorded position within the Antelope Valley Limestone. Also known from the Antelope Valley Limestone at Meiklejohn Peak, Nevada (Ross, 1972).

Remarks.—This fragmentary cranidium conforms to the description of *Bathyurellus* sp. 3 of Ross (1972) in the length (sag.) and shape of the glabella, the declined and posteriorly set palpebral lobes, the moderately rounded anterior glabella lobe, and the lack of an occipital furrow. Ross (1972) noted the similarity between this species and *Uromystrum pogonipensis* (Hintze, 1953, p. 138, pl. 10, figs. 11–19) from the *Pseudoolenoides dilectus* Zone (Zone M) at Ibex. *Uromystrum pogonipensis*, however, appears to have a longer anterior border, subhorizontal palpebral lobes, axial furrows that were better impressed posteriorly and weaker anteriorly, and a glabella that was less constricted at the palpebral lobes than seen in the Nevada specimens.

Fortey (1979, p. 90) restricted the generic concept of *Bathyurellus* and reillustrated material of the type species, *Bathyurellus abruptus* Billings (1865). The cranidia associated with the lectotype pygidium of *B. abruptus* possess subparallel axial furrows that result in a rectangular outline for the glabella. *Uromystrum* (see Whittington, 1953, p. 658–660, pl. 67, figs. 1, 2), however, exhibits sinuous axial furrows and a glabella that is constricted at the palpebral lobes. Further, the occipital furrow of the type species is weakly impressed axially and seems to have become more faint laterally. *Bathyurellus* sp. 3, therefore, conforms more closely to the generic concept of *Uromystrum* and is reassigned. This parallels the reassignment of *Bathyurellus pogonipensis* to *Uromystrum* (Ross, 1972, p. 34).

Uromystrum sp. 3 (Ross) is illustrated from float to provide a more complete assessment of faunal diversity

in the Antelope Valley Limestone at the Whiterock Canyon Narrows.

Family Dimeropygiidae Hupé, 1953
Genus *Dimeropygiella* Ross, 1951

Type species.—*Dimeropygiella caudanodosa* Ross, 1951, by original designation, from the Ibexian Garden City Formation of Utah.

Dimeropygiella cf. *D. caudanodosa* Ross, 1951
Figure 14.7–14.9

- cf. 1951 *Dimeropygiella caudanodosa* Ross, p. 124, pl. 35, figs. 18, 22–28.
- cf. 1953 *Dimeropygiella caudanodosa*; Hintze, p. 154, pl. 19, figs. 5, 10.
- cf. 1963 *Ischyrotoma caudanodosa*; Whittington, p. 47.
- cf. 1979 *Ischyrotoma caudanodosa*; Fortey, p. 106.
- cf. 1989 *Ischyrotoma* cf. *I. caudanodosa*; Dean, p. 36, pl. 28, figs. 7, 9, 10, 13, 15–17.
- cf. 1994 *Ischyrotoma caudinodosa* [sic]; Chatterton, p. 543, fig. 1, table 1.
- cf. 2001 *Dimeropygiella caudanodosa*; Adrain et al., p. 964, figs. 7.24–7.50, 8, 9.

Holotype.—Cranidium, Yale Peabody Museum (YPM) 18217, Ibexian Garden City Formation, Utah.

Remarks.—A single, small, corroded cranidium was recovered from float (WCN F25–40) in the Ninemile Formation that exhibits an elongate, ovate glabella, and a narrow (tr.) anterior border that is not overhung by the anterior lobe of the glabella. While this is consistent with *Dimeropygiella caudanodosa*, the size and corroded nature of the specimen dictates that it be treated with a degree of uncertainty. A small pygidium, recovered from the same interval (WCN F25–40), is broadly similar to the pygidia illustrated for *D. caudanodosa* in the number of axial rings and the development of the post-axial nodes and is treated in a like manner.

Dimeropygiella blanda (Hintze, 1953, p. 155–156, pl. 19, figs. 6–8; Adrain et al., 2001, p. 967, figs. 13, 14, 15.1–15.11) has a distinct preglabellar field, a broad (tr.) anterior border, and a glabella that is more broadly ovate than in *D. caudanodosa*. *Dimeropygiella ovata* (Hintze, 1953, p. 155, pl. 19, figs. 1–4; Adrain et al., 2001, p. 965, figs. 10, 11.1–11.8, 11.10–11.12) has a wide (tr.) anterior border and a glabella that is more broadly ovate in outline. *Dimeropygiella fillmorensis* Adrain et al. (2001, p. 965–967, figs. 11.9, 12), similarly, has a broad (tr.) anterior border and a glabella that is more broadly ovate in outline.

Family Telephinidae Marek, 1952
Genus *Carolinites* Kobayashi, 1940

Type species.—*Carolinites bulbosus* Kobayashi, 1940, by original designation, from the Caroline Creek Sandstone of Tasmania.

Carolinites sibiricus Chugaeva, 1964
Figure 14.11–14.14

1964 *Carolinites sibiricus* Chugaeva, p. 45, pl. 1, figs. 4, 5.

- 1967 *Carolinites angustagena* Ross, p. D10, pl. 3, figs. 29–39.
- 1974 *Carolinites angustagena*; Shaw, p. 10, pl. 1, figs. 29–34, pl. 2, figs. 1–4, 7, 8.
- 1975 *Carolinites sibiricus*; Fortey, p. 111, pl. 40, figs. 1–10, 12, 13.
- 1999 *Carolinites sibiricus*; Fortey and Droser, p. 187, fig. 3.11–3.13.
- 1999 *Carolinites sibiricus*; McCormick and Fortey, fig. 3.22, 3.23, 3.27–3.29.

Diagnosis.—See Fortey, 1975, p. 111.

Occurrence.—Previously known from Siberia (Chugaeva, 1964), the Profilbekken Member of the Valhallfonna Formation of Spitzbergen (Fortey, 1975), the Joins Formation of Oklahoma (Shaw, 1974), and the Antelope Valley Limestone of California (Ross, 1967) and Nevada (Fortey and Droser, 1999). This report extends the known range of the species downward from the Antelope Valley Limestone into the Ninemile Formation.

Material and occurrence.—Total of 10 cranidia and four pygidia from the Ninemile Formation from WCN-143 (1-0-0), WCN-146 (1-1-0), WCN-159 (3-2-0), and WCN-160 (1-0-0), and the Antelope Valley Limestone from WCN-177 (1-0-0), WCN-178 (2-0-0), and WCN-190 (0-1-0).

Remarks.—We have accepted the synonymy of *Carolinites angustagena* Ross with *C. sibiricus* Chugaeva outlined by Fortey (1975). Specimens recovered from the Ninemile Formation at the Whiterock Canyon Narrows conform to those illustrated from the overlying Antelope Valley Limestone (Fortey and Droser, 1999) in the shape and proportions of the glabella, the width of the palpebral areas, the width of the posterior area, and the relative size of the bacculae.

Genus *Oopsites* Fortey, 1975

Type species.—*Telephus hibernicus* Reed in Gardiner and Reynolds, 1909, by original designation, from the Tourmakeady Limestone of Ireland.

Oopsites sp.
Figure 14.10

Remarks.—Although crushed, the cranidium recovered from the Ninemile Formation collection WCN-113 conforms to the genus *Oopsites* in the large, anteriorly placed palpebral lobes and anteriorly rounded glabella. The presence of the scattered granulose prosopon and single pair of lateral glabellar furrows are reminiscent of *Oopsites hibernicus* (Reed in Gardiner and Reynolds, 1909) (see Adrain and Fortey, 1997, p. 101, pl. 11, figs. 10–12, 15, pl. 13, figs. 1–3, pl. 16, fig. 24).

Order Ptychopariida Swinnerton, 1915
Family Harpetidae Hawle and Corda, 1847
Harpetidae indet.
Figure 14.15

Remarks.—A single fragmentary cephalon from collection WCN-64 is assigned to the family Harpetidae on the basis of a pitted cephalic fringe. This fragment is reminiscent of *Selenoharpes* sp. (Ross, 1972, p. 36, pl. 16, figs. 7, 8) from the Antelope Valley Limestone at the Meiklejohn Peak bioherm in the arcuate nature of the fringe in dorsal view and its slight convexity (sag.).

Conclusions

Moderately diverse trilobite faunas characteristic of the uppermost Ibexian Series (Zone J, the “*Pseudocybele nasuta*” Zone) and the lowermost Whiterockian Series (Zone L, the *Psephosthenaspis pseudobathyurus* Zone, the *Orthidiella* Zone) are present in the Whiterock Canyon Narrows section, Nevada. A cryptic unconformity separates these two faunas as demonstrated by approximately 10 m of paleobathymetric relief along a channel scoured into shale and interbedded limestone in the upper Ninemile Formation. An alternative section that lacks evidence of an unconformity should be sought to serve as the type section across the base of the Whiterockian Stage.

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