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Cambrian trilobites from the Nounan Dolomite and lower St. Charles Formation (upper Marjuman to lower Sunwaptan; Miaolingian to Furongian Series), Smithfield Canyon, northern Utah

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Non-Technical Summary.—Distinctive changes in carbon isotope curves are used extensively alongside trilobite faunal turnover in the international correlation of Cambrian strata. One such isotopic signature, called "SPICE" (Steptoean Positive Isotope Carbon Excursion), is widely used, but in North America, the co-occurring trilobite fossils have never been illustrated. We here describe, discuss, and illustrate the 34 trilobite species (two new) that occur below, within, and above the SPICE from the same section where the carbon isotope data were collected in Utah. The illustration of the specimens, rather than just listing taxa, allows other scientists to evaluate the conclusions made here: the SPICE began in the *Aphelaspis* Biochron and ended within the *Elvinia* Biochron.

Abstract.—The trilobite faunas that occur with the Steptoean Positive Isotope Carbon Excursion (SPICE) at Smithfield Canyon, Utah, have been reported, but not illustrated. Given the importance of the SPICE at this section for international correlations, the trilobites from new collections from the upper Nounan Dolomite to lower St. Charles Formation at Smithfield Canyon are reported herein and integrated with the previously reported taxa. Trilobite assemblages indicate that the upper *Cedaria* to the *Ellipsocephaloides* biozones (Miaolingian Series, Guzhangian Stage to Furongian Series, Jiangshanian Stage) are present stratigraphically below or above the SPICE.

Some of the taxa reported herein may represent new species, but they are not represented by well-enough preserved specimens and are left in open nomenclature. However, *Kingstonia smithfieldensis* n. sp. and *Bromella utahensis* n. sp. are named on the basis of common and well-preserved specimens.

New carbon isotope data from Smithfield Canyon from an overlapping section of the lower St. Charles Formation, that add to the overall shape of the SPICE curve, are presented. The new $\delta^{13}C$ values above the *Elvinia* Biozone range from –0.36‰ to +1.5‰, confirming that the SPICE concludes within the *Elvinia* Biozone.

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Introduction

The Steptoean Positive Isotope Carbon Excursion (SPICE) is an event broadly used for correlation of the Furongian Series worldwide (Saltzman et al., 2004; Geyer, 2019; Peng et al., 2020). The strata containing the SPICE record in northern Utah provides a continuous high-resolution $\delta^{13}C$ stratigraphy for the upper Miaolingian to Furongian series along with a detailed trilobite biostratigraphy and U–Pb calibrated maximum depositional ages of <494 Ma (Cothren et al., 2022). This combination of features makes this SPICE record in northern Utah probably one of the most important SPICE records in Laurentia and worldwide and allows for testing ideas about correlation, biologic evolution, and the Cambrian timescale.

The Smithfield Canyon section of northern Utah is one of the fundamental locations used to establish the SPICE as an event for international correlation (Saltzman et al., 2004; Geyer, 2019; Peng et al., 2020), and the trilobites from this section are important for establishing the Laurentian biostratigraphic range of the SPICE and its international correlation. The base of the international Furongian, Paibian Stage, is determined by the first appearance of the *Glyptagnostus reticulatus* (Kobayashi, 1938) in Paibi, China. Biostratigraphic correlation of the base of the Furongian to Laurentia is based on the first appearance of *G. reticulatus*, which co-occurs with *Aphelaspis* fauna at the base of the Steptoean Stage of Laurentia (Palmer 1962; Peng et al., 2004). However, agnostids, which are crucial in international correlations (Peng et al., 2020), are essentially absent from the lower part of the Smithfield Canyon section; thus, correlations require the use of polymeroid trilobites, which are less cosmopolitan.

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The trilobites used for the original biostratigraphy in Smithfield Canyon were identified by Allison Palmer in Saltzman et al. (2004), but unfortunately they were never illustrated to allow re-evaluation of the identifications. The recent high-resolution δ^{13}C stratigraphic study by Cothren et al. (2022) re-documented the SPICE at this section and calibrated it using high-precision chemical abrasion–isotope dilution thermal ionization mass spectrometry (CA-ID-TIMS) of detrital zircons, yielding maximum depositional ages (MDAs) of the excursion and additional trilobite collections with preliminary results.

The goal of this study is to present the details of the trilobite paleontology of the new material collected for this geochemical analysis and provide refinement of the biostratigraphy originally reported by Saltzman et al. (2004). A parallel goal is to present new δ^{13}C chemostratigraphy from a measured section that overlaps with the SPICE section from Cothren et al. (2022) to better identify the end of the SPICE.

Geologic background

Regional geology of the Nounan and St. Charles formations.—The Cambrian (Marjuman–Sunwaptan) Nounan and St. Charles formations are part of a thick Ediacaran–Devonian stratal package exposed in the Bear River Range of southeastern Idaho and northern Utah (e.g., Maxey, 1958; Fig. 1.1). The St. Charles Formation (300 m thick) is divided into the basal ~20 m thick, siliciclastic-rich Worm Creek Member and overlying informal upper carbonate member. In the northernmost exposures of these strata, in southeastern Idaho, the Worm Creek Member and the underlying Nounan Dolomite (300 m thick) contain two to four laterally discontinuous, overall upward-fining cycles of feldspathic arenite that transition to micrite and dolomicrite, wackestone, and packstone (Wakeley, 1975; Todt, 2014; Link et al., 2017). The upper Nounan and lower St. Charles formations are regionally correlative to the upper Frenchman Mountain Dolostone, Dunderberg, and Nopah formations in the central Great Basin, Utah, Nevada, and Arizona (Rowland and Korolev, 2011; Karlstrom et al., 2020; Rowland et al., 2023); the Bonanza King and Nopah Formations in Death Valley, CA (Montañez et al., 2000); and the Orr Formation in the House Range, Utah (Baker, 2010; Fig. 2).

While for much of western Laurentia, the late Cambrian is a period of putative tectonic quiescence, this region experienced dynamic magmatism and uplift. A combination of normal faulting and thermal subsidence south (current geography) of the dextral-normal Snake River Transfer Fault created the Worm Creek depocenter (Lund, 2008), which received clastic detritus from Cambrian plutons exhumed by uplift of the Lemhi Arch (Link et al., 2017). Quartzites of the Worm Creek Member are interpreted to represent the influx of siliciclastic sediment at the second-order Sauk II–III transition maximum lowstand within the greater transgressive regime across Laurentia during Cambrian time (Sloss, 1963; Saltzman et al., 2004).

Smithfield Canyon, Utah.—In Smithfield Canyon, the upper 160 m of the Nounan Formation is characterized by digitate stromatolites, thrombolites (including a prominent 7 m stacked

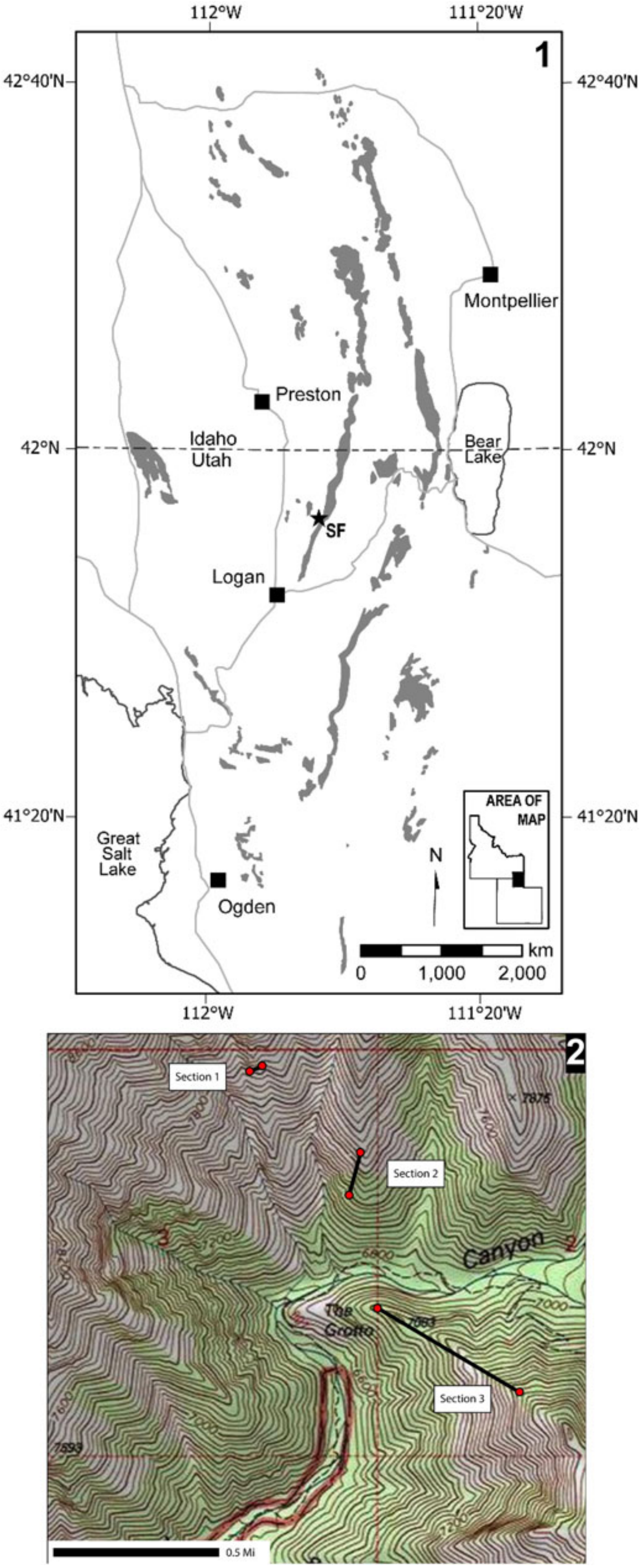

Figure 1. (**1**) Map showing the location of the Smithfield Canyon section (black star, "SF") in regional context. Gray polygons represent the aerial extent of mapped Nounan and St. Charles formations. Modified from the Stage Geologic Map Compilation (Horton et al., 2017) and Wakeley (1975). (**2**) Portion of the Naomi Peak 7.5-foot quadrangle showing the locations of the three measured sections. Basemap: 2013 National Geographic USA topographic map, projection: NAD 1983 UTM Zone 12N.

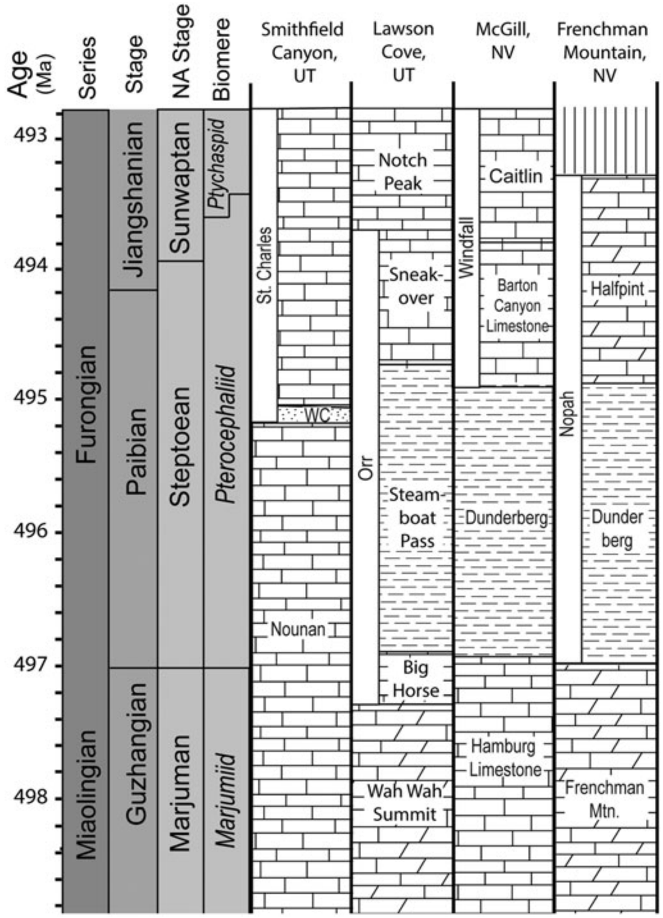

Figure 2. Working hypothesis for the correlation of the Nounan and St. Charles formations in northern Utah with formations in the Great Basin. Approximated biomere boundaries and their corresponding estimated time boundaries. NA = North American; WC = Worm Creek Member; Mtn = Mountain.

thrombolite complex), sandy trilobite grainstones, imbricated intraclastic conglomerates, oolitic packstone to grainstones, and a 0.25 m thick calcareous sandstone horizon (Fig. 3). Hummocky cross-stratified to swaley-bedded, plane-bedded, rippled sandy grainstones and imbricated intraclastic conglomerates indicate storm deposition at or below fair-weather wave base. Ptygmoidal injectites and associated convolute laminae may suggest local, syndepositional seismic activity (Pratt, 1998; Kahle, 2002; Pratt and Ponce, 2019). Causal seismicity is likely linked to the emplacement and uplift of the Lemhi arch and/or movement along the Snake River Transform Fault to the Northeast (Lund, 2008; Link et al., 2017; Pratt, 2021).

The upper contact between the Nounan Formation and the overlying Worm Creek Member is seemingly gradational with an increase in siliciclastic material up-section. The Worm Creek Member comprises tan to pale-pink variably dolomitic orthoquartzites that are fine- to medium-grained, trough-cross bedded, and plane bedded. At the top of the member, orthoquartzites are interbedded with thin cryptalgal carbonate beds, suggesting a gradational contact. The lower part of the overlying informal upper member of the St. Charles Formation is lithologically similar to the uppermost Nounan Formation at this locality, dominated by sandy trilobite grainstone.

Carbon isotopes

The δ^{13}C stratigraphy in Smithfield Canyon covers the uppermost 160 m of the Nounan Formation, the entire 20 m Worm Creek Member, and the lower 60 m of the upper member of the St. Charles Formation, coinciding with nine trilobite biozones (Figs. 3, 4; Cothren et al., 2022; this paper). A prominent +5‰ excursion in $\delta^{13}C_{carb}$ has been identified as the SPICE (Saltzman et al., 2004; Cothren et al., 2022). In the upper *Cedaria* and *Crepicephalus* biozones, δ^{13}C values range from –0.5‰ to +1‰, the excursion rises to peak values of +5‰ in the *Aphelaspis*, *Prehousia,* and *Dunderbergia* biozones, and exhibits a plateau over 35 m (136–171 m) within the *Dunderbergia* and *Elvinia* biozones before returning to near background values within the *Elvinia* Biozone. Analyses of detrital zircons from three siliciclastic horizons in this section give MDAs of 494.35 ± 0.46 Ma (n = 6), 494.16 ± 0.46 Ma (n = 10), and 492.84 ± 0.73 Ma (n = 3; Cothren et al., 2022).

The δ^{13}C values in the strata overlying those presented by Cothren et al. (2022) gradually decrease toward background values within the *Elvinia*, *Taenicephalus*, and *Ellipsocephaloides* biozones (193–245.5 m), capturing apparent carbon cycle stabilization following the SPICE. The δ^{13}C values range from –0.36‰ to +1.5‰, with a mean value of +0.71‰. The δ^{18}O values have a weak correlation with δ^{13}C values ($R^2 = 0.35$), indicating that the δ^{13}C values are likely primary (Fig. 3). The end of the SPICE is defined as the inflection point in which the rate of change (first derivative) of the LOESS fit of δ^{13}C values returns to 0, indicating no change. From our analysis, the SPICE concludes at 191 m, within the *Elvinia* Biozone, stratigraphically above the last occurrence (LO) of *Irvingella*.

These new data allow a complete profile of the SPICE to be captured. The end of the SPICE within the *Elvinia* Biozone, stratigraphically above the LO of *Irvingella,* follows similar trends in the Great Basin, in which the SPICE concludes in the upper *Elvinia* Biozone, above the *I. major* subzone, with δ^{13}C values stabilizing toward near background values in the *Taenicephalus* Biozone (Saltzman et al., 1998). We do not observe the small +3‰ δ^{13}C excursion near the Pterocephaliid–Ptychaspid biomere boundary recorded in Smithfield Canyon by Saltzman et al. (2004). While two points, at 241 m and 243 m, depart from background values at ∼2‰, this is not a well-defined "excursion" as it lacks a rising or falling limb. The post-SPICE positive excursion captured by Saltzman et al. (2004) may not be recorded in this work due to lower sampling resolution and/or uncertainty regarding the section location and lack of data availability from Saltzman et al. (2004). Alternatively, rock may be missing due to a subtle unconformity or hiatal surface; however, biostratigraphy points toward a near-continuous section.

Biostratigraphy

Saltzman et al. (2004) presented the initial biostratigraphy of the SPICE in Smithfield Canyon on the basis of material identified by Allison Palmer (in Saltzman et al., 2004). Unfortunately, none of the trilobite specimens that this biostratigraphy was based on have been illustrated. This paper integrates the list of taxa identified by Palmer present in the Institute of Cambrian

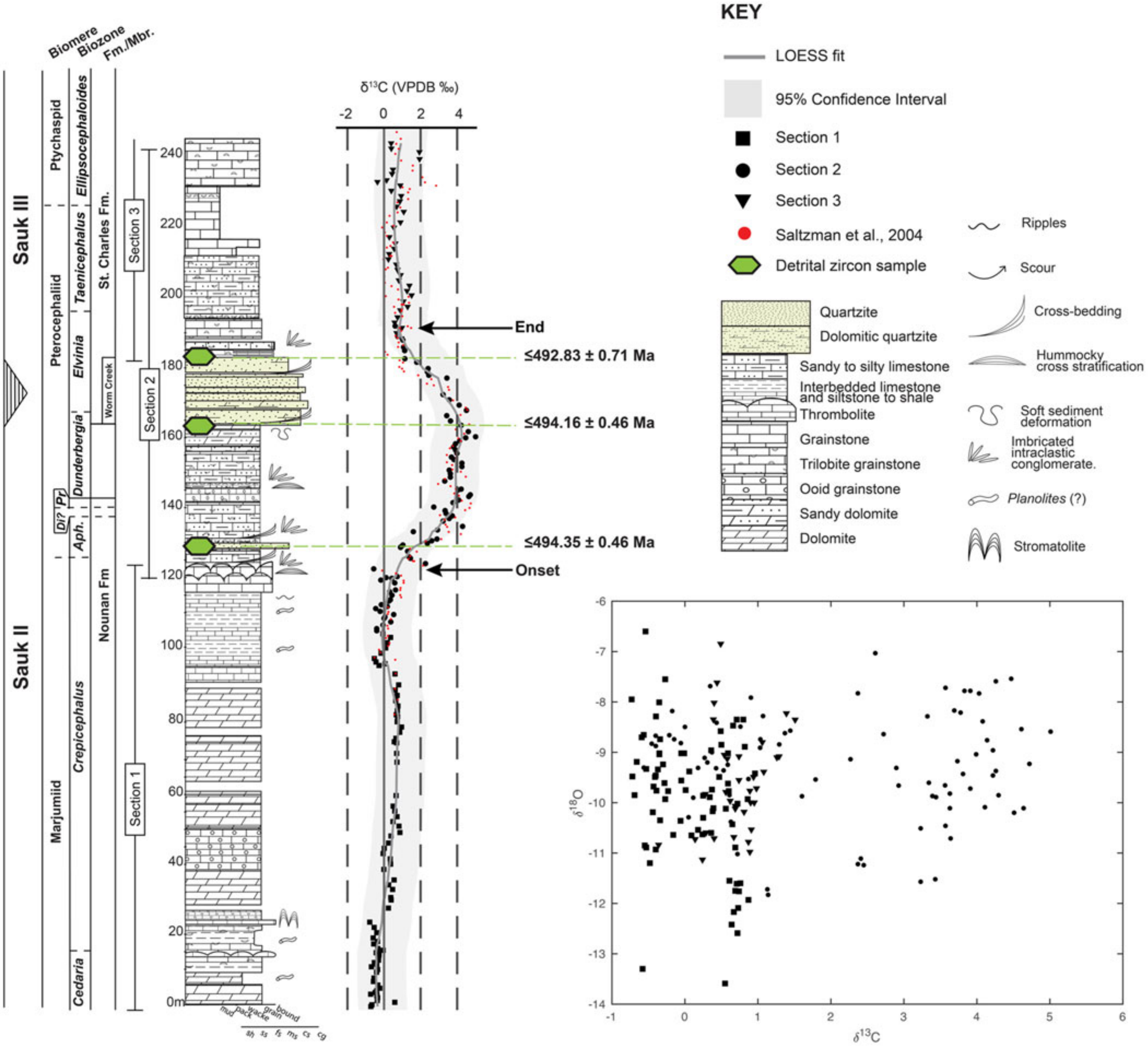

Figure 3. Composite lithostratigraphy of the Smithfield Canyon sections, estimated Sauk II–III boundary, biozones, and biomeres. Solid lines indicate well-defined biostratigraphic boundaries (e.g., first occurrence and last occurrence of biozone fauna are <1 m), and dashed lines indicate estimated biozone boundary position; $\delta^{13}C$ stratigraphy: black points are from this study, and red points are from Saltzman et al. (2004); $\delta^{13}C$ and $\delta^{18}O$ cross plot indicating a lack of co-variation between $\delta^{13}C$ and $\delta^{18}O$ values and arguing that $\delta^{13}C$ values are likely primary. *Aph* = *Aphelaspis; Di* = *Dicanthopyge; Pr* = *Prehousia*; Fm. = Formation; Mbr. = Member; VPBD = Vienna PeeDee Belemnite. Modified from Cothren et al. (2022).

Studies (ICS; data provided by M. Webster, personal communication, 2022) and the new collections made for this study.

Trilobite materials collected for this study occur in the Nounan and St. Charles formations and range from the *Cedaria* to *Ellipsocephaloides* biozones. These biozones represent the upper Marjuman, Steptoean, and lower Sunwaptan stages of Laurentia and the international upper Guzhangian, Paibian, and lower Jiangshanian stages of the Miaolingian and Furongian series.

The *Cedaria* Biozone is presently poorly documented on the basis of the occurrence of *Glaphyraspis* sp. indet., *Coosia*? sp. indet., and *Menomonia* cf. *M*. *turberculata* Rasetti, 1965 at USNM loc. 44289. The biozone diagnostic species is *Menomonia* cf. *M*. *turberculata*, which is known from a single librigena with the characteristic ornamentation and shape of *M*. *turberculata*. This taxon is from the *Cedaria* Biozone of the Maryville Limestone of the East Coast (Rasetti, 1965). By contrast, *Glaphyraspis* sp. indet., represented here by small cranidia, is similar to an unnamed species typically found in the lower portion of the *Crepicephalus* Biozone in the Great Basin (Eby, 1981). The small cranidia identified as *Coosia*? sp. indet. could belong to meraspides of any related taxon to *Coosia*. No pygidia are associated with the cranidia.

The *Crepicephalus* Biozone is well documented in the section on the basis of fauna from USNM loc. 44290 that include *Welleraspis*? sp. indet., *Genevievalla* sp. indet., *Coosina* cf.

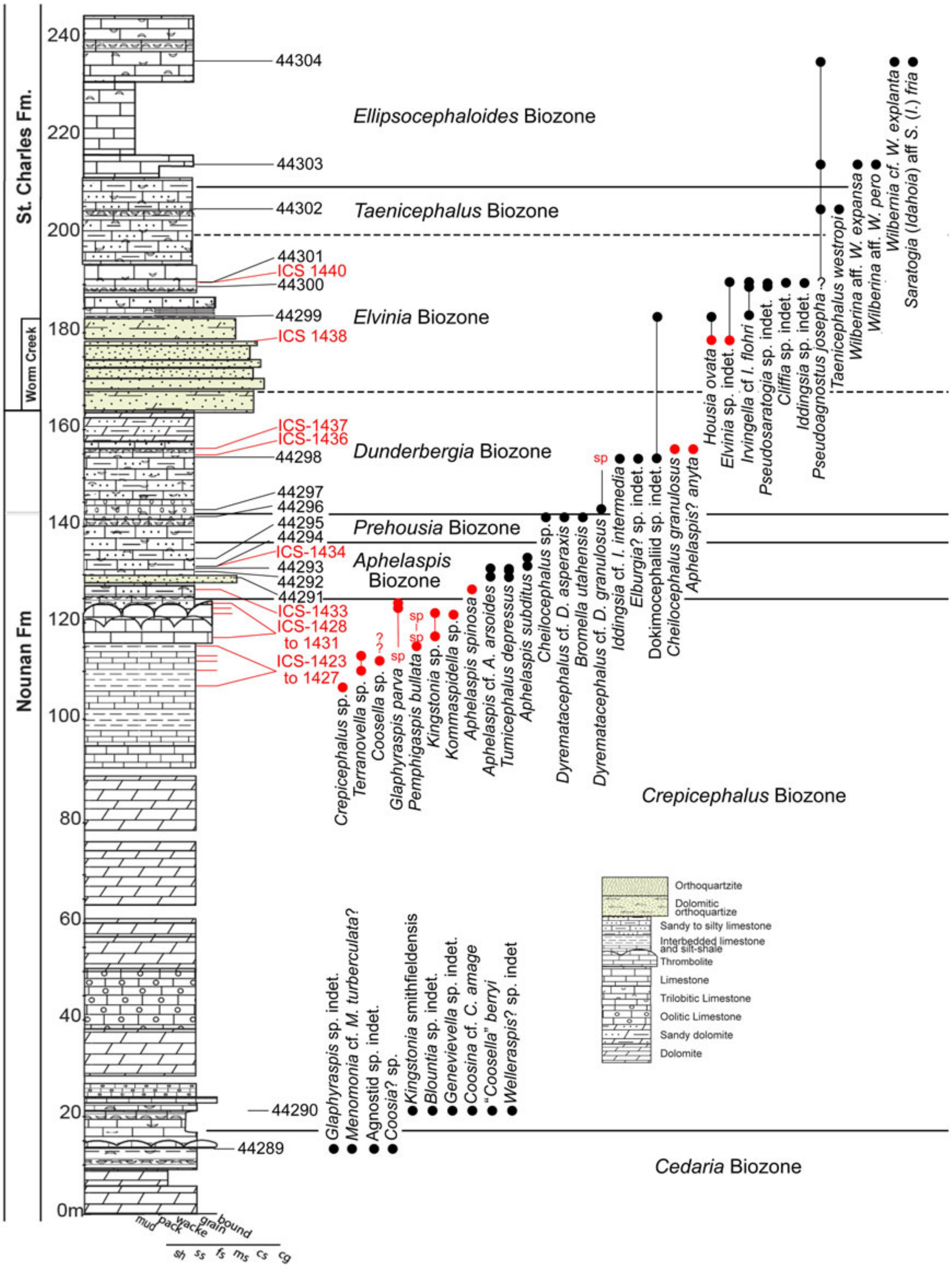

Figure 4. Composite stratigraphic column and trilobite ranges of the upper Nounan and lower St. Charles formations from Smithfield Canyon, Utah. Taxa occurrences and localities listed in red represent data from Saltzman et al. (2004); those listed in black represent new data from this study. sp = no specific identification by Saltzman; ? = questionable occurrence of the taxon. Section modified from Cothren et al. (2022).

C. amage (Walcott, 1916b), “*Coosella*” *berryi* (Lochman, 1940), *Blountia* sp., and *Kingstonia smithfieldensis* n. sp. Palmer in Saltzman et al. (2004) reported in ascending order *Crepicephalus* sp. (ICS-1423), *Terranovella* sp. (ICS-1424, 1426), *Coosella*? sp. (ICS-1425, 1426, 1428?), *Glaphyraspis* sp. 1 (ICS-1426), *Pemphigaspis bullata* Hall, 1863, (ICS-1427), *Pemphigaspis* sp. (ICS-1428, 1429), *Kingstonia* sp. (ICS-1428, 1429), and *Komaspidella*? sp. (ICS-1429). *Crepicephalus* is diagnostic of the biozone, and *Coosina amage* occurs in the *Crepicephalus* Biozone of Tennessee (Rasetti, 1965). “*Coosella*” *berryi* is known from the upper *Cedaria* and/or lower *Crepicephalus* biozones in Missouri (Lochman, 1940), Virginia (Rasetti, 1965), Pennsylvania (Tasch, 1951), and Utah (Robison, 1960; Eby, 1981), and *Genevievalla* sp. indet. from the Nounan Formation is found in the upper *Cedaria* Biozone of the House Range (Eby, 1981). These two taxa suggest that USNM loc. 44290 may represent the lowermost portion of the *Crepicephalus* Biozone.

The *Aphelaspis* Biozone is well documented in the section on the basis of fauna from USNM locs. 44291–44294 that include *Aphelaspis subditus* Palmer, 1962 and *Aphelaspis* cf. *A. arsoides* Rasetti, 1965. *Aphelaspis subditus*, which is found in the upper two horizons, Palmer (1965, p. 60) reported from the upper part of the *Aphelaspis* Biozone. Palmer (1965, p. 90) stated that *Tumicephalus depressus* Palmer, 1965 is commonly found in the *Dicanthopyge* Biozone; however, its occurrence in the Nounan with *Aphelaspis* cf. *A. arsoides* and below *A. subditus* puts that in question. Palmer in Saltzman et al. (2004) identified *Glaphyraspis parva* (Walcott, 1899) from a 2 m interval (ICS-1430–1432), which he believed represents the lower *Aphelaspis* Biozone and possibly the crisis interval at the base of the Steptoean. Above these samples, Palmer reported *Aphelaspis spinosa* Palmer, 1954 (ICS-1433), *Aphelaspis* sp. 1 (ICS-1434), and *Bromella*? sp. (ICS-1434). MDAs associated within the *Aphelaspis* Biozone in Smithfield Canyon indicate that the Furongian Epoch, Paibian Age, and Steptoean Age must be ≤494.4 ± 0.5 Ma (Cothren et al., 2022).

The *Dicanthopyge* Biozone has not been documented in the section by either Saltzman et al. (2004) or this study. However, *Tumicephalus depressus,* which occurs with *Aphelaspis* spp. in the Nounan Formation, is typically found in the *Dicanthopyge* Biozone of Nevada and Utah (see Palmer, 1965).

The *Prehousia* Biozone is documented in the section on the basis of fauna from USNM locs. 44298–44296 that contains *Bromella utahensis* n. sp., *Cheilocephalus* sp. indet., and *Dytremacephalus* cf. *D. asperaxis* Palmer, 1965. Palmer (1965, p. 85) reported *Bromella veritas* Palmer, 1965 and *D. asperaxis* from the *Dicanthopyge* and *Prehousia* biozones. He also reported a *Dytremacephalus* species similar to *D. granulosus* Palmer, 1954 from the *Prehousia* Biozone. The *Cheilocephalus* sp. indet. pygidia are similar to *Cheilocephalus brachyops* Palmer, 1965, *C. brevilobus* (Walcott, 1916b), and *C. granulosus* Palmer, 1965. These taxa occur in the *Aphelaspis* to *Elvinia* biozones according to Palmer; thus, their occurrence here in the *Prehousia* Biozone is reasonable. Palmer in Saltzman et al. (2004) did not report any taxa from the *Prehousia* Biozone.

The *Dunderbergia* Biozone is documented in the section on the basis of fauna from USNM locs. 44297 and 44298 that contain *Dytremacephalus* cf. *D. granulosus*? Palmer, 1954, *Elburgia*? sp. indet., and *Iddingsia* cf. *I. intermedia* Palmer, 1965. *Dytremacephalus granulosus* is known from the basal *Dunderbergia* Biozone, *Elburgia* spp. occurs in the middle to upper *Dunderbergia* Biozone, and *Iddingsia intermedia* Palmer, 1965 are found in the upper *Dunderbergia* Biozone according to Palmer (1965). Palmer in Saltzman et al. (2004) identified *Dytremacephalus* sp. (ICS-1436), *Aphelaspis*? *anyta* (Hall and Whitfield, 1877; ICS-1437 [originally reported as *Dunderbergia anyta*]), and *Cheilocephalus granulosus* Palmer, 1965 (ICS-1437), which he suggested may represent the lower *Dunderbergia* Biozone. These samples occur below the Worm Creek Quartzite in the top of the Nounan Formation.

The *Elvinia* Biozone is documented in the section on the basis of fauna from USNM locs. 44299 and 44301 that contain *Cliffia* sp. indet., *Elvinia* sp. indet., *Housia ovata* Palmer, 1960, *Iddingsia* sp. indet., *Irvingella* cf. *I. flohri* Resser, 1942, and *Pseudosaratogia* sp. indet. *Cliffia* spp., *Housia ovata*, *Elvinia* spp., *Iddingsia* spp. *Irvingella flohri*, and *Pseudosaratogia* spp. are known from the *Elvinia* Biozone (Wilson, 1951; Palmer, 1965; Westrop, 1986; Pratt, 1992). Palmer in Saltzman et al. (2004) identified *Elvinia?* sp. (ICS-1438), *Housia ovata* (ICS-1438), *Irvingella* sp. (ICS-1439), *Kindbladia* sp. (ICS-1439), and *Irvingella* cf. *I. flohri* (ICS-1440), which he suggested may represent the lower to mid-*Elvinia* Biozone. These samples occur above the Worm Creek Quartzite in the base of the overlying upper member of the St. Charles Formation. MDA in the *Elvinia* Biozone, below the first occurrence of *Irvingella*, suggests the base of the Jiangshanian Stage is ≤492.83 ± 0.71 Ma (Cothren et al., 2022). This correlation is based on the co-occurrence of *Agnostotes orientalis* (Kobayashi, 1935) and *Irvingella angustilimbus* (Kobayashi, 1938) at the Jiangshanian Global Stratotype Section and Point (Palmer, 1965; Peng et al., 2012).

The *Taenicephalus* Biozone is documented in the section on the basis of fauna from USNM loc. 44302 that contains *Taenicephalus westropi* Chatterton and Gibb, 2016, *Kendallina* sp. indet., and *Pseudagnostus josepha* (Hall, 1863). *Kendallina* species are known from the *Taenicephalus* Biozone of Alberta (Westrop, 1986; Chatterton and Gibb, 2016). Palmer in Saltzman et al. (2004) did not report any taxa from this biozone.

The *Ellipsocephaloides* Biozone is documented in the section on the basis of fauna from USNM locs. 44303 and 44304 that contain *Saratogia* (*Idahoia*) aff. *S.* (*I.*) *fria* Lochman and Hu, 1959, *Wilbernia* cf. *W. explanata* (Whitfield, 1880), *Wilbernia* aff. *W. expansa* Frederickson, 1949, *Wilbernia* aff. *W. pero* (Walcott, 1890), and/or *Pseudagnostus josepha*. These or closely related species are known from the upper *Taenicephalus* to *Ellipsocephaloides* biozones (Frederickson, 1949; Lochman and Hu, 1959; Grant, 1962; Westrop, 1986). Palmer in Saltzman et al. (2004) did not report any taxa from this biozone.

Materials and methods

Materials.—All specimens were found as isolated sclerites and for the most part in poorly fossiliferous strata. As a result, the association of different sclerites is presumed to represent a single taxon if similar associations have been previously reported (e.g., Palmer, 1965; Westrop, 1986; Sundberg, 1999). However, at localities with multiple taxa present, association of the different sclerites is difficult. As a result, several taxa are herein left in open nomenclature following Bergstrom (1988), with "cf." representing that the material is not abundant or well-enough preserved to demonstrate that it firmly belongs to the assigned taxon and "aff." used to designate a probable new species affiliated with the species, but the samples and or preservation of the specimens are not enough to justify naming a new species.

Illustrated specimens have been coated with colloidal graphite followed by ammonium chloride sublimate. Specimen orientation for photography and measurements is primarily with the cranidial anterior border and/or palpebral lobes, librigenal border, or pygidial border in a horizontal plane. Some photographs of specimen counterparts (negative relief) have been digitally inverted using Adobe Photoshop and are labeled in the figure captions as "inverted." This inversion included changing positive images to negatives (changing black to white and vice versa) and flipping the image horizontally.

Some materials are not preserved well enough to justify illustration, but they are mentioned so their occurrence can be noted (e.g., Agnostid sp. indet.).

Carbon isotopes.—Sample preparation and carbon-isotope analyses were conducted using the methods outlined by Cothren et al. (2022, supplemental data).

Repositories and institutional abbreviations.—Specimens discussed within this paper are housed in the United States Natural History Museum (USNM). Other abbreviations include American Museum of Natural History (AMNH) and Institute of Cambrian Studies, University of Chicago (ICS).

Systematic paleontology

Sundberg is responsible for all taxonomic assignment of the new material from Smithfield Canyon.

Phylum Arthropoda von Siebold, 1848

Remarks.—Citation of the authorship of the phylum has been variable; however, Hegna et al. (2013) discussed this inconsistency in the authorship, demonstrating that Arthropoda von Siebold, 1848 is the correct citation.

Class Uncertain
Order Agnostida Salter, 1864
Family Agnostidae M'Coy, 1849
Agnostid sp. indet.

Remarks.—A single, very small cephalon was found from the Nounan Formation (USNM loc. 44289), which cannot be identified to generic level and is left in open nomenclature.

Subfamily Pseudagnostinae Whitehouse, 1936
Genus *Pseudagnostus* Jaekel, 1909

Type species.—*Agnostus cyclopyge* Tullberg, 1880 from the Alum Shale, Andrarum, southern Sweden (by original designation).

Pseudagnostus josepha (Hall, 1863)
Figure 5

1863 *Agnostus josepha* Hall, p. 178, pl. 6, figs. 54, 55.
2000 *Pseudagnostus josepha* Peng and Robison (see for previous synonymy; also see remarks that follow).
2007 *Pseudagnostus josepha*; Sundberg et al., p. 795, fig. 3.3.

Holotype.—Cotypes AMNH 311 cranidium and pygidium preserved as sandstone molds *Agnostus josepha* Hall, 1863 (p. 178, pl. 6, figs. 54, 55; see Shergold, 1977, pl. 15, figs. 9, 10).

Occurrence.—St. Charles Formation (*Elvinia*? to *Ellipsocephaloides* biozones), Smithfield Canyon, Utah (see Appendix).

Remarks.—There are conflicting views as to which species of *Pseudagnostus* are valid or definable. Peng and Robison (2000) and Chatterton (2020) viewed *P. josepha* as a variable species that includes several previously named species. By contrast, Westrop and Eoff (2012) viewed the taxa of *Pseudagnostus* as more constrained in morphology and removed some taxa that Peng and Robison (2000) included in their synonymy. Of note is Westrop and Eoff's (2012, p. 208) removal of *P. communis* (Hall and Whitfield, 1877) from *P. josepha* that was proposed by Peng and Robison (2000). Westrop and Eoff (2012, p. 209) pointed out that the type material of *P. communis* has never been photographically illustrated and is poorly known from the type area. Chatterton and Gibb (2016; Chatterton 2020) noted that *P. josepha* is widespread in the McKay Group, Canada, but is designated as *Pseudagnostus* cf. *P. josepha* due to its quality of preservation.

The limited samples preserved in limestone from the St. Charles Formation show a combination of features of *P. josepha* preserved in limestone from Alberta (Westrop, 1986) and China (Peng and Robison, 2000) and *Pseudagnostus* cf. *P. communis* preserved in limestone from Newfoundland (Westrop and Eoff, 2012). In terms of cephalon shape (cephalon length/width ratio), the grouping of the St. Charles Formation specimens with the China and Alberta specimens of *P. josepha* (Fig. 6.1) and their separation from *Pseudagnostus* cf. *P. communis* from Newfoundland suggest their placement within *P. josepha*. This ratio changes during ontogeny from around 97% to 106% cephalic length for *P. josepha*. By contrast, *Pseudagnostus* cf. *P. communis* from Newfoundland show a gradual decrease from 94% to 90% of cephalic length, suggesting Westrop and Eloff's (2012) separation of the Newfoundland specimens from the Alberta and China specimen. Glabellar widths (tr., measured at the termination of the basal lobes) of the samples from the St. Charles Formation are a bit wider than *P. josepha* from China and Alberta (Fig. 6.2); however, these three localities form an overall trend of glabellar width around 35% to 40% of cephalon width from 2.0 to 4.5 mm in cephalon length. By contrast, the material of *Pseudagnostus* cf. *P. communis* from Newfoundland centers around 33% of cephalon width regardless of cephalon length (1.5 to 5.0 mm), again justifying the separation of the Newfoundland specimens of *P. josepha*. Other cephalic differences between the St. Charles Formation specimens from the Newfoundland specimens include a larger and subcircular M3 delineated with a distinct F2 similar to the China specimens and a shallower median glabellar furrow, although this feature is variable in both the Newfoundland and China specimens. Overall, the St. Charles Formation specimens are most like *P. josepha*.

Four partial cephala from USNM loc. 44289 are similar to *P. josepha*, but without associated pygidia, they cannot be firmly assigned to this species.

Class Trilobita Walch, 1771
Order "Ptychopariida" Swinnerton, 1915
Suborder "Ptychopariina" Richter, 1933

Remarks.—See Sundberg and Webster (2022) for comments on the order and suborder of ptychopariidids.

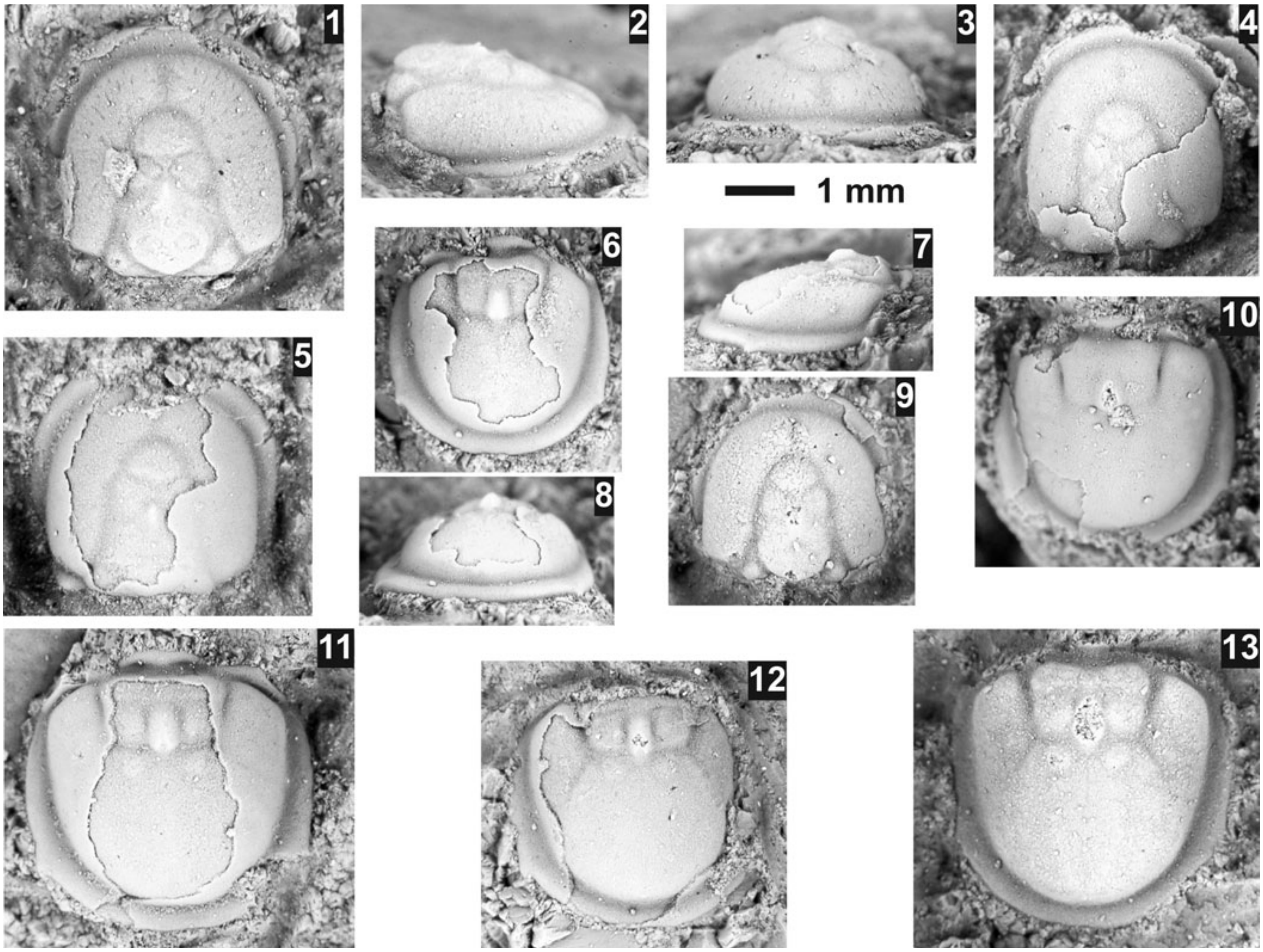

Figure 5. *Pseudagnostus josepha* (Hall, 1863) from the Sunwaptan Stage, St. Charles Formation, Smithfield Canyon, Utah. All specimens are from USNM loc. 44304. (**1–3**) Exfoliated cephalon USNM 775702: (**1**) dorsal view; (**2**) lateral view; (**3**) anterior view. (**4**) Partially testate cephalon USNM 775706. (**5**) Mostly testate cephalon USNM 775705. (**6–8**) Mostly testate pygidium USNM 775700: (**6**) dorsal view; (**7**) lateral view; (**8**) anterior view. (**9**) Exfoliated cephalon USNM 775703. (**10**) Testate pygidium USNM775704. (**11**) Mostly testate pygidium USNM 775707. (**12**) Mostly exfoliated pygidium USNM 775699. (**13**) Exfoliated pygidium USNM 775701.

Superfamily Olenacea Burmeister, 1843
Family Aphelaspididae Palmer, 1960
Subfamily Aphelaspidinae Palmer, 1960

Remarks.—Lee and Chatterton (2005) discussed the placement of this subfamily on the basis of the ontogeny of several species of *Aphelaspis*. They suggested that Aphelaspidinae (*Housia* and *Aphelaspis*) is closely related to Olenidae and should be placed into the superfamily Olenacea, but not in the family Pterocephaliidae. By contrast, Hopkins (2011) illustrated that Housiinae and Pterocephaliinae are sister clades when compared with the Aphelaspidinae.

Genus *Aphelaspis* Resser, 1935

Type species.—*Aphelaspis walcotti* Resser, 1938, Nolichucky Formation, Virginia (by original designation).

Aphelaspis subditus Palmer, 1962
Figure 7.1–7.11

1962 *Aphelaspis subditus* Palmer, p. 35, pl. 4, figs. 20–22.
2005 *Aphelaspis subditus*; Lee and Chatterton, p. 1360, pl. 5, figs. 1–6, 10, 21, 26 (see for further synonymy).
2022 *Aphelaspis subditus*; Cothren et al., figs. 2.9, 2.11.

Holotype.—USNM143173a, cranidium, from the Dunderberg Formation, Cherry Creek, Nevada, USA.

Occurrence.—Nounan Formation (*Aphelaspis* Biozone), Smithfield Canyon, Utah (see Appendix); upper Bonanza King and lower Dunderberg Shale formations (*Aphelaspis* Biozone), Nevada (Palmer, 1965); Rabbitkettle Formation (*Olenaspella regularis* Biozone), Mackenzie Mountains, District of Mackenzie, Canada (Pratt, 1992).

Remarks.—The specimens from USNM 44294 are most like *A. subditus* in the construction of the frontal area of the cranidium and shape of the librigena. However, the pygidium is more of a rectangular outline and is more like

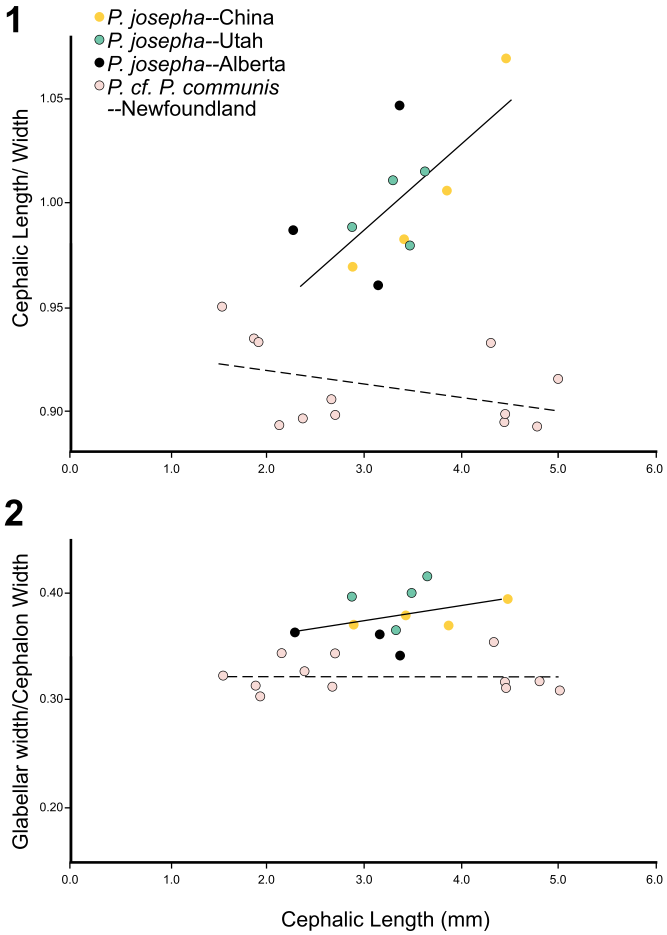

Figure 6. Bivariate plots of limestone specimens of *Pseudagnostus josepha* (Hall, 1863) from China (Peng and Robison, 2000), Alberta (Westrop, 1986), and Utah (this study) and *Pseudagnostus* cf. *P. communis* from Newfoundland (Westrop and Eoff, 2012). (**1**) Cephalic length/width ratio versus cephalic length (mm), illustrating a different trend of *P.* cf. *P. communis* (dashed line) compared with specimens of *P. josepha*. (**2**) Glabellar width/cephalon width versus cephalic length (mm), again showing different trends between the two taxa.

A. brachyphaspis Palmer, 1962. This is not unexpected given that Palmer (1965, fig. 10) suggested that this species gave rise to *A. subditus*. The specimens from USNM 44295 (Fig. 7.11) have a more elongated pygidium, more typical of the species. Palmer (1965, p. 60) reported this species from the upper part of the *Aphelaspis* Biozone.

A more unusual feature of these specimens from USNM 44294 is that the occipital ring has essentially two small occipital nodes, one near the middle of the ring and the other posterior, near the posterior margin (Fig. 7.2, 7.4). This is not a feature of *A. subditus* or any other member of the genus from the Great Basin. However, Rasetti (1965) reported *A. arses* (Walcott, 1916a) from the Nolichucky Formation from Tennessee that has both an occipital spine and a node. Furthermore, another species with a large occipital spine similar to *A. arsoides* reported from Tennessee (Rasetti, 1965) occurs in the Worm Creek section at USNM 44292. *Aphelaspis arses*, *A. arsoides*, and *A. spinosa* are the only three members of the species that have occipital spines. Specimens from USNM loc. 44295 have only one occipital node.

Aphelaspis cf. *A. arsoides* Rasetti, 1965
Figure 7.12–7.20

1965 *Aphelaspis arsoides* Rasetti, p. 94, pl. 11, figs. 15–21, pl. 12, fig. 22.

Holotype.—USNM144677, cranidium, from the Nolichucky Formation, Jefferson County, Tennessee, USA.

Occurrence.—Nounan Formation (*Aphelaspis* Biozone), Smithfield Canyon, Utah (see Appendix).

Remarks.—The specimens assigned to this species are similar to the type material from the Nolichucky Formation, Tennessee, in having a long, flat-lying, and narrow occipital spine (Fig. 7.13, 7.17), horizontal intraocular region, pitting in the furrows of the cranidium (Fig. 7.14), librigenal features, and pygidial features. These specimens are dissimilar from the Tennessee species in the absence of an occipital spine in smaller specimens and less-pronounced pitting in the cranidial and librigenal anterior borders, which is the reason for the cf. designation. These specimens differ from *A. arses* also from Tennessee in the latter's possession of a dorsally arched, broad-based, occipital spine; pitting in the furrows of the cranidium; and more-divergent anterior branches of the facial sutures. The specimens are also very similar to the *A. subditus* from USNM loc. 44294, but the latter lacks the long occipital spine in specimens of the same size, pitting in the cranidial furrows, and the nearly horizontal intraocular regions. This species is also similar to *A. spinosa* Palmer, 1954 in the possession of an occipital spine but differs in having a narrower anterior border and better-defined anterior border furrow. Saltzman et al. (2004) reported *A. spinosa* from ICS-1433, which occurs approximately 1 m below the first occurrence of *Aphelaspis* cf. *A. arsoides* reported here.

Genus *Bromella* Palmer, 1965

Type species.—*Bromella veritas* Palmer, 1965, Dunderberg Shale, Nevada (by original designation).

Remarks.—Palmer (1965) discussed the similarity of *Bromella* to *Aphelaspis*, *Dytremacephalus*, and *Prehousia*, but the differences between these genera and *Bromella* are consistent as outlined by Palmer (1965).

Bromella utahensis new species
Figure 8

2022 *Bromella veritas*, Cothren et al., fig. 2.6, 2.10.

Holotype.—Pygidium USMN 775678 from the Nounan Formation, Smithfield Canyon, Utah (USMN loc. 44296).

Paratypes.—Specimens USMN 775669–775677 and 775679–775683 from the Nounan Formation, Smithfield Canyon, Utah (USMN loc. 44296).

Diagnosis.—Pygidium with relatively long axis, four axial rings, and well-defined pleural furrows.

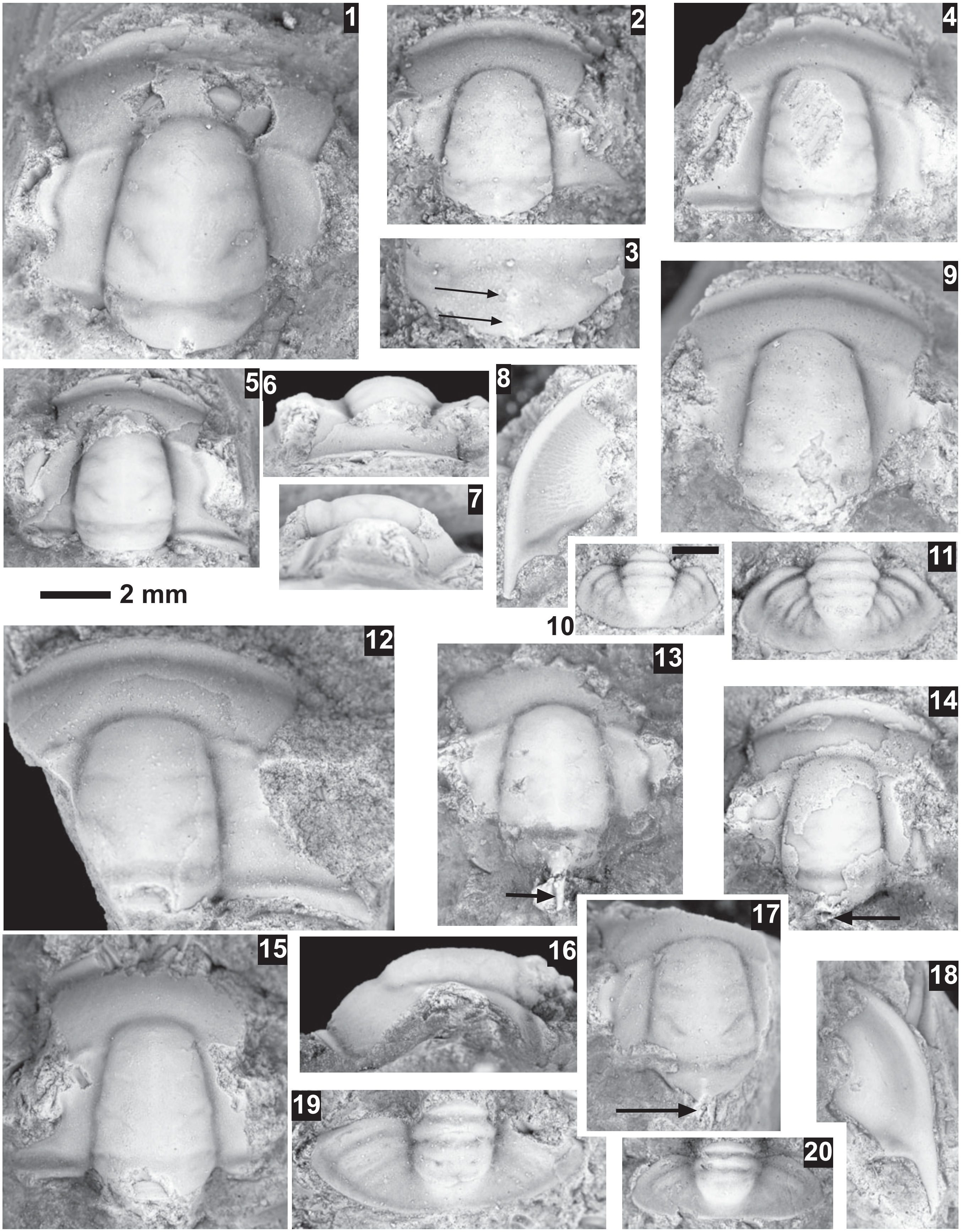
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Figure 7. *Aphelaspis* species from the Steptoean Stage, upper Nounan Formation, Smithfield Canyon, Utah. All specimens use the 2 mm scale bar unless otherwise noted. (**1–11**) *Aphelaspis subditus* Palmer, 1962 from USNM loc. 44294 unless otherwise noted: (**1**) exfoliated cranidium USNM 775644; (**2, 3**) exfoliated cranidium USNM 775642, close-up of occipital ring showing two nodes (arrows); (**4**) exfoliated cranidium USNM 775648; (**5–7**) mostly exfoliated cranidium USNM 775649: (**5**) dorsal view; (**6**) anterior view; (**7**) lateral view; (**8**) testate librigena USNM 775645; (**9**) exfoliated cranidium USNM 775643; (**10**) exfoliated pygidium USNM 775646 from USNM loc. 44295, scale bar = 1 mm; (**11**) exfoliated pygidium USNM 775647. (**12–20**) *Aphelaspis* cf. *A. arsoides* Rasetti, 1965 from USNM loc. 44291 unless otherwise mentioned: (**12**) mostly exfoliated cranidium USNM 775639 (USNM loc. 44293); (**13**) exfoliated cranidium USNM 775638 (USNM loc. 44293) showing long occipital spine (arrow); (**14**) partially testate cranidium USNM 775634 showing spine (arrow); (**15, 16**) exfoliated cranidium USNM 775637: (**15**) dorsal view; (**16**) lateral view; (**17**) exfoliated partial cranidium USNM 775635 showing spine (arrow); (**18**) exfoliated librigena USNM 775640 (USNM loc. 44293); (**19**) exfoliated pygidium USNM 775636; (**20**) exfoliated pygidium USNM 775641 (USNM loc. 44293).

Occurrence.—Nounan Formation (*Prehousia* Biozone), Smithfield Canyon, Utah (see Appendix).

Description.—Cranidium of moderate size, length 6.7 ± 1.0 mm (N = 6); subpentagonal, moderate convexity (sag. and trans.); anterior margin moderately and unevenly curved, slightly arched dorsally; posterior margin (excluding occipital ring) directed laterally. Anterior branches of facial sutures divergent by 22 ± 5° from anterior border*;* posterior branches strongly divergent at 41 ± 6°. Glabella elongate, conical shaped, length 71 ± 2% cranidial length; width 51 ± 4% cranidial width; tapered; width at anterior end 71 ± 2% of posterior glabellar width; moderate convexity (sag. and trans.); frontal lobe rounded. Axial furrows moderately deep; preglabellar furrow forming deep pits laterally and shallow medially. Lateral glabellar furrows shallow; S1 bifurcated and deepest; S2 and S3 projected slightly posteriorly; S4 projected laterally and very faint. Occipital ring slightly elevated above rest of glabella, moderately convex; length 19 ± 1% glabellar length; posterior margin moderately convex posteriorly, with small occipital node. SO straight to very slightly curved anteriorly medially; deepest laterally; moderate depth. Frontal area length 29 ± 2% cranidial length, unequally divided. Preglabellar field slightly convex, moderately downsloping, length 66 ± 5% frontal area length. Anterior border very slightly convex, flat to upsloping, length 34 ± 5% frontal area length, slightly tapering laterally, no medial inbend or swelling. Anterior border furrow moderate depth, curvature of 146 ± 4°. Fixigena slightly convex, nearly level, anterior area strongly downsloping anteriorly, width 38 ± 4% of posterior glabellar width. Palpebral lobes moderately curved, slightly elevated, narrow, and moderately long, length 40 ± 3% glabellar length; anterior margin located transversely opposite of S3 or L4. Ocular ridge well defined, directed slightly posterolaterally from glabella at 73 ± 3° to sagittal axis. Posterior area of fixigena triangular, projected slightly posterolaterally, terminated with sharply rounded corner; length 30 ± 3% glabellar length; width 57 ± 9% glabellar length.

Librigenae moderate size, length approximately 7.5–7.8 mm (N = 2); moderately wide at about 56–59% length without spine; lateral margin moderately curved. Genal field slightly convex. Border moderately convex, slightly widening and flattening posteriorly, width about 13–20% librigenal width; border furrow moderate depth, shallowing posteriorly. Librigenal spine moderate length, about 50–64% librigenal length; broad based and flattened, directed posterolaterally.

A single hypostome possibly belonging to the species is subrectangular with narrow lateral and posterior borders and furrows, oval anterior lobe, and crescent-shaped posterior lobe approximately 25% of hypostomal length. Thin anterior border with broadening triangular wing structures laterally.

Rostral plate and thorax unknown.

Pygidium small to moderate length, length 1.5–2.0 mm (N = 3); subrectangular shaped, length 48–52% width; margin smooth with faint undulations/spines? on posterior margin, anterior margin strongly and evenly curved directed slightly posterolaterally; anterolateral corners sharply rounded, transversely opposite posterior portion of axis; no postaxial notch; moderately convex (sag.). Axis moderately tapered, mid-width 83–86% anterior width, anterior width 40–43% pygidial width; length 81–88% pygidial length, extends to nearly posterior border furrow; four axial rings, moderately convex; terminal piece moderate size, rounded posteriorly; axial ring furrows moderate depth. Pleural regions convex, downsloping around margin; pleural furrows narrow and moderately deep, shallowing posteriorly, extending to border furrow; other pleural furrows shallow. Border not slightly convex to flat, broader (tr.) laterally and narrower (sag.) medially. Border furrow well defined, shallows medially.

Fine granules occur on the cranidia, librigenae, and pygidia testate surfaces, smooth on internal surfaces. Terrace lines on the cranidial anterior border and lateral and ventral margins of the librigenal border. Genal caeca occurs on frontal area and genal area of librigena. Exoskeleton relatively thin.

Etymology.—Named after the type locality in Utah.

Remarks.—The pygidia from the Nounan Formation differ from the two pygidia of *Bromella veritas* Palmer, 1965 (pl. 18, figs. 5, 9) in possessing longer axes with three to four axial rings and more-pronounced pleural bands and furrows although they are roughly the same length (≈2 mm) as Palmer's illustrated specimens. These differences are the justification for assigning the Nounan specimens to a new species. Cranidial and librigenal features of both *B. utahensis* and *B. veritas* are very similar, except that the former has a granulated exoskeleton and smooth internal mold, whereas the latter has a pitted, smooth, or finely granulated surface.

Family Elviniidae Kobayashi, 1935
Subfamily Elviniinae Kobayashi, 1935
Genus *Dytremacephalus* Palmer 1954

Type species.—*Dytremacephalus granulosus* Palmer, 1954, Riley Formation, Texas (by original designation).

Dytremacephalus cf. *D. asperaxis* Palmer, 1965

Figure 9.1–9.3

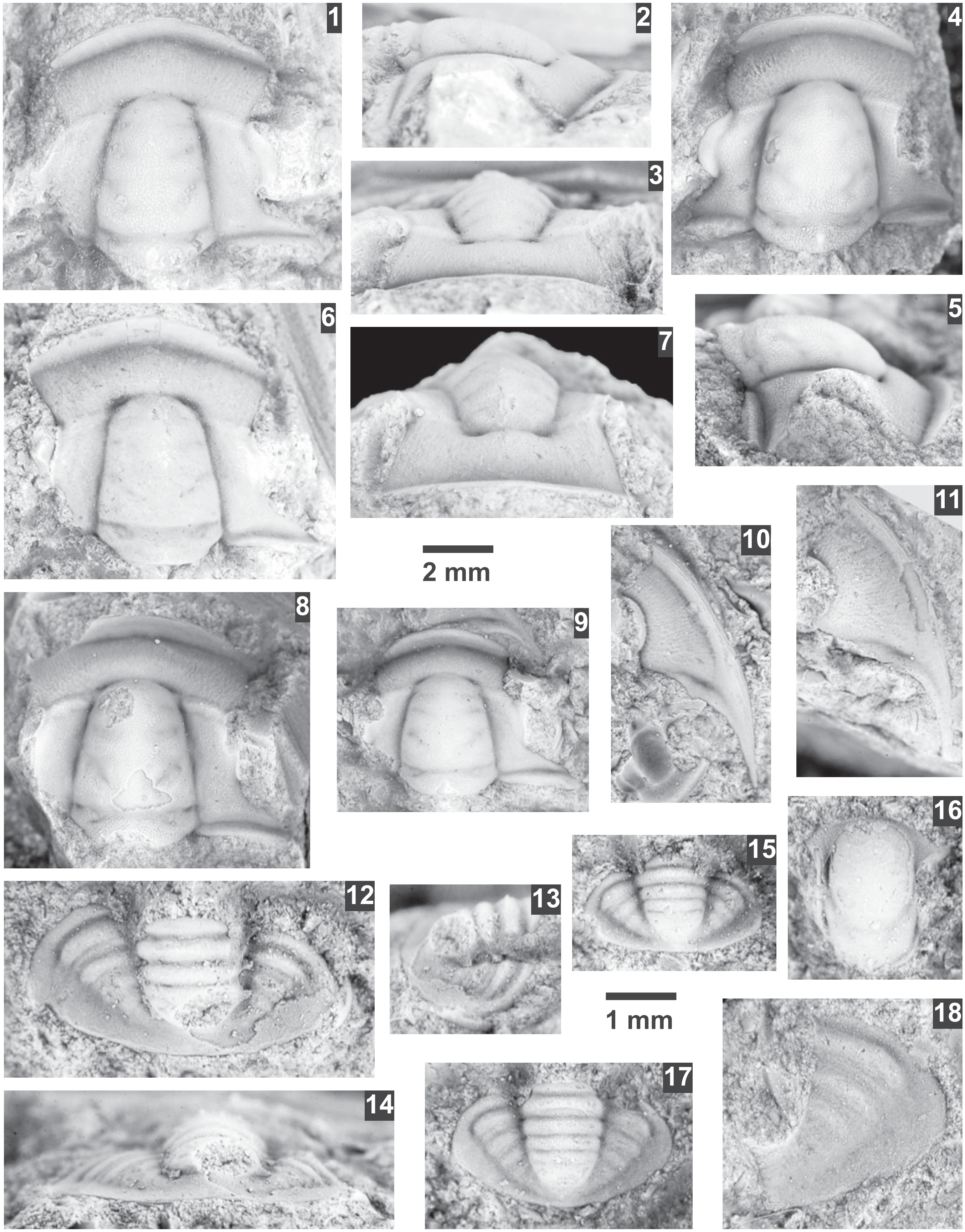
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Figure 8. *Bromella utahensis* n. sp. from the *Prehousia* Biozone, Steptoean Stage, upper Nounan Formation, Smithfield Canyon, Utah. All specimens are from USNM loc. 44296 and paratypes unless otherwise mentioned. (**1–3**) Exfoliated cranidium USNM 775676: (**1**) dorsal view; (**2**) lateral view; (**3**) anterior view. (**4, 5**) Testate cranidium USNM 775673: (**4**) dorsal view; (**5**) lateral view. (**6, 7**) Exfoliated cranidium USNM 775672. (**8**) Testate cranidium USNM 775675. (**9**) Testate cranidium USNM 775674. (**10**) Testate librigena USNM 775677. (**11**) Testate librigena USNM 775679. (**12–14**) mostly exfoliated pygidium USNM 775681: (**12**) dorsal view; (**13**) lateral view; (**14**) posterior view. (**15**) Exfoliated pygidium USNM 775682. (**16**) Mostly exfoliated hypostome USNM 775680. (**17**) Exfoliated, holotype pygidium USNM 775678. (**18**) Exfoliated, partial pygidium USNM 775683. (**1–11**) Specimens use the 2 mm scale; (**12–18**) specimens use the 1 mm scale bar.

1965 *Dytremacephalus asperaxis* Palmer, p. 85, pl. 18, figs. 10–13l.

2022 *Dytremacephalus* cf. *D. asperaxis*, Cothren et al., fig. 2.12.

Holotype.—USNM 141761, cranidium, from the Dunderberg Formation, Bastian Peak, Nevada, USA.

Occurrence.—Nounan Formation (*Dunderbergia* Biozone), Smithfield Canyon, Utah (see Appendix).

Remarks.—These specimens are very similar to the type material of *Dytremacephalus asperaxis* Palmer, 1965 in overall cranidial and librigenal features. The "cf." designation is the result of the palpebral lobes appearing to be slightly longer and the surface slightly more granular in these specimens, but it is difficult to ascertain given the fragmentary nature of the Smithfield Canyon specimens. This species is also similar to *D. granulosus* Palmer, 1954, but the latter differs by its coarser surface granulation.

Dytremacephalus cf. *D. granulosus* Palmer, 1954

Figure 9.4, 9.5

1954 *Dytremacephalus granulosus* Palmer, p. 750, pl. 85, figs. 5, 6.

1965 *Dytremacephalus granulosus*, Palmer, p. 85, pl. 18, figs. 14, 16–19, 21.

Holotype.—USNM 123319, cranidium, from the Lion Mountain Sandstone, Riley Formation, White Creek, Texas, USA.

Occurrence.—Nounan Formation (lower *Dunderbergia* Biozone), Smithfield Canyon, Utah (see Appendix).

Remarks.—The materials from USNM loc. 44297 are fragmentary and cannot be placed in confidence. These specimens differ from *D. granulosus* from Texas in having a finer granulation and a more convex anterior border. The species from USNM loc. 44297 are unusual because of their granulated sclerites and relatively deeper glabellar furrows than most taxa from the *Aphelaspis, Dicanthopyge*, and *Prehousia* biozones.

Genus *Elburgia* Palmer, 1960

Type species.—*Crepicephalus* (*Loganellus*) *granulosus* Hall and Whitfield, 1877, Dunderberg Formation, Nevada (by original designation).

Elburgia? sp. indet.

Figure 10.5–10.7

Occurrence.—Nounan Formation (*Dunderbergia* Biozone), Smithfield Canyon, Utah (see Appendix).

Remarks.—The material from USNM 44298 is small cranidia, mostly exfoliated and fragmented; thus, their placement within the genus or to a specific species is not possible. The material is tentatively assigned to *Elburgia* due to the overall glabellar shape, character of the glabellar furrows, and relatively long palpebral lobes. Ontogenetic changes may explain differences in relative glabellar shape and length, palpebral length and positions, and length of the preglabellar area observed in smaller specimens from the larger specimens illustrated by Palmer (1965; for example, see in these morphologies during ontogeny illustrated by Sundberg, 2020; Sundberg and Webster, 2022).

Genus *Elvinia* Walcott, 1924

Type species.—*Dikelocephalus roemeri* Shumard, 1861, Wilberns Formation, Texas (by original designation).

Elvinia sp. indet.

Figure 11.4

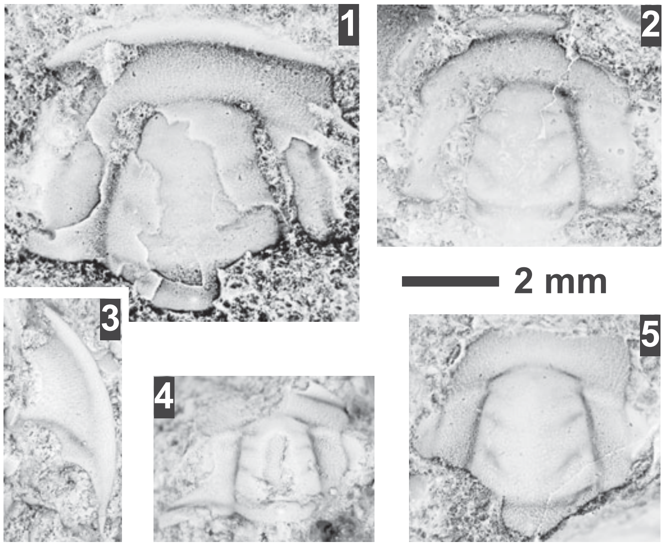

Figure 9. *Dytremacephalus* spp. from the *Prehousia* and *Dunderbergia* biozones, Steptoean Stage, Nounan Formation, Smithfield Canyon, Utah. (**1–3**) *Dytremacephalus* cf. *D. asperaxis* Palmer, 1965 from USNM loc. 44296: (**1**) partial, mostly testate cranidium USNM 775695, photograph inverted; (**2**) exfoliated cranidium USNM 775696, photograph inverted; (**3**) testate librigena USNM 775697. (**4**) Small cranidium USNM 775693. (**5**) Cranidium USNM 775694, inverted photograph.

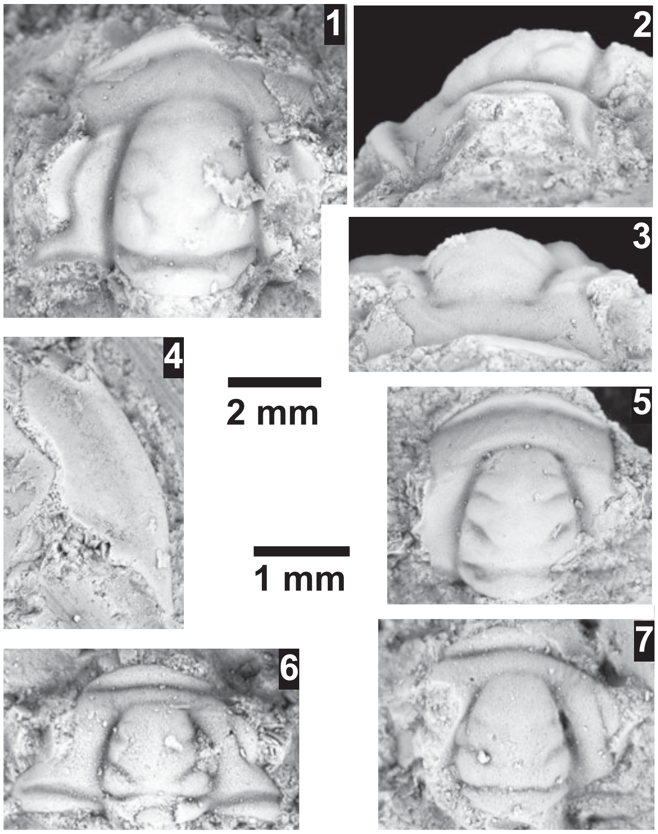

Figure 10. Trilobites from the *Dunderbergia* Biozone, Steptoean Stage, upper Nounan Formation, Smithfield Canyon, Utah. All specimens are from USNM loc. 44298. (**1–4**) Dokimocephaliid indet.: (**1–3**) partial, exfoliated cranidium USNM 775687: (**1**) dorsal view; (**2**) anterior view; (**3**) lateral view; (**4**) exfoliated librigena USNM 775688. (**5–7**) *Elburgia*? sp. indet.: (**5**) exfoliated cranidium USNM 775689; (**6**) small cranidium USNM 775690; (**7**) small partial cranidium USNM 775691. (**1–5**) Specimens use the 2 mm scale bar; (**6, 7**) specimens use the 1 mm scale bar.

Occurrence.—St. Charles Formation (*Elvinia* Biozone), Smithfield Canyon, Utah (see Appendix).

Remarks.—A single large, well-preserved pygidium from USMN loc. 44301 (Fig. 11.4) is very similar to the pygidium of *Elvinia roemeri* (Shumard, 1861) illustrated by Westrop (1986, p. 30, fig. 15), Chatterton and Ludvigsen (1998, figs. 23, 24), Chatterton and Gibb (2016, pl. 33–35), and Chatterton (2020, fig. 8.3, 8.4), differing in the greater angulation of the lateral anterior border. With no additional specimens or other associated exoskeleton parts, this specimen is left in open nomenclature.

Genus *Irvingella* Ulrich and Resser in Walcott, 1924

Type species.—*Irvingella major* Ulrich and Resser in Walcott, 1924, Franconia Formation, Wisconsin (by original designation).

Irvingella cf. *I. flohri* Resser, 1942
Figure 12.1–12.5

1942 *Irvingella flohri* Resser, p. 24, pl. 4, figs. 12–14.
1942 *Irvingella adamsensis* Resser, p. 24, pl. 4, figs. 7–11.
1956 *Irvingella* aff. *I. flohri*; Deland and Shaw, p. 556, pl. 66, figs. 10–12.
1965 *Irvingella flohri*; Palmer, p. 47, pl. 6, figs. 16, 19, 20, 24.
2016 *Irvingella flohri*; Westrop and Adrain, p. 410, figs. 9, 10A–C, H–J (see for complete synonymy).
2022 *Irvingella flohri*?; Cothren et al., figs. 2.2–4.

Holotype.—USNM 108667, cranidium, from the Dunderberg (?) Formation (USGS loc. 60), Eureka, Nevada, USA.

Occurrence.—St. Charles Formation (*Elvinia* Biozone), Smithfield Canyon, Utah (see Appendix); Dunderberg Shale and unnamed limestone (middle *Elvinia* Biozone), Nevada and Utah (Palmer, 1965).

Remarks.—This species is known only from the middle part of the *Elvinia* Biozone, but the specimens from this horizon are broken. The genal fields of the cranidia of the larger specimens are not well preserved, but they appear to be similar to *I. flohri*. A smaller cranidium (Fig. 12.4) and pygidium (Fig. 12.5) are also similar to the smaller cranidium and pygidium of *I. flohri* illustrated by Westrop and Adrain (2016, fig. 9G–K), although the cranidial anterior border and border furrow are very faint in the specimen reported here. Due to the fragmentary nature of the larger specimens, these samples are questionably placed into *I. flohri*.

Palmer in Saltzman et al. (2004) reported *Irvingella* cf. *I. flohri* from ICS-1440 in Smithfield Canyon.

Subfamily Dokimocephalinae Kobayashi, 1935
Dokimocephaliid indet.
Figure 10.1–10.4

2022 *Apachia prima*, Cothren et al., fig. 2.8.

Occurrence.—St. Charles Formation (*Dunderbergia* Biozone), Smithfield Canyon, Utah (see Appendix).

Remarks.—Three cranidia and two librigena from USNM loc. 44298 have the typical features of dokimocephaliids in a prominent, tapered to egged-shaped glabella, relatively narrow fixigena, strongly unevenly curved anterior border, and relatively long palpebral lobes. Included in this group are *Apachia* Frederickson, 1949, *Kindbladia* Frederickson, 1948, and *Dunderbergia* Walcott, 1924 (Palmer, 1965 assigned this genus to the subfamily Elviniinae). These specimens were originally assigned to *A. prima* Palmer, 1965 by Cothren et al. (2022); however, they do not possess the strongly inflated glabella and strongly downsloping preglabellar area typical of the type species, *A. trigonis* Frederickson, 1949 (pl. 70, figs. 16, 17), or *A. butlerensis* (Fredrickson, 1949) and *A. prima* (see Palmer, 1965, pl. 3, figs. 5, 10, 15). The specimens are similar to *Kindbladia affinis* (Walcott, 1884) or *K. wichitaensis* (Resser, 1942; see Westrop, 1986) but differ in their shallower lateral glabellar furrows, more-rounded anterior lobe, and longer palpebral lobes. The species *Dunderbergia brevispina* Palmer, 1965 and *D. calculosa* Palmer, 1965 and some specimens of *D. variagraulata* Palmer, 1954 (see Palmer, 1965, pl. 5, fig. 4) also have similar features to the cranidia and librigena from the St. Charles Formation, but the former generally differ in shallower lateral glabellar furrows, shorter palpebral lobes, and/or more elevated palpebral lobes.

Due to the limited samples of this taxon from the St. Charles Formation and the lack of pygidia, these specimens are left in open nomenclature. A possible specimen was found in collection USNM loc. 44299.

Genus *Iddingsia* Walcott, 1924

Type species.—*Ptychoparia similis* Walcott, 1884, Dunderberg Formation, Nevada (by original designation).

Iddingsia sp. indet.

Figure 11.5–11.9

Occurrence.—St. Charles Formation (*Elvinia* Biozone), Smithfield Canyon, Utah (see Appendix).

Remarks.—Relatively large librigenae similar to *I. similis* (Walcott, 1884) are from USMN loc. 44301. These librigenae have a broad, convex lateral border that terminates in a long and curved genal spine (see Palmer, 1965, pl. 2, fig. 1). Of particular note, Westrop et al. (2010) assigned librigenae with genal spines that are narrower based and shorter to *Iddingsia* and related taxa.

A poorly preserved pygidium with a semicircular outline, narrow border, tapering axis with four axial rings, and weakly defined pleural and intrapleural furrows is similar to pygidia assigned to *Kindbladia* by Frederickson (1948, pl., fig. 21) and Palmer (1965, pl. 3, fig. 4). However, Hohensee and Stitt (1989) assigned a transversely elongated pygidium with a very blunt axis as belonging to the type species of *Kindbladia*, *K. wichitaensis* (Resser, 1942). Hohensee and Stitt (1989, p. 870) suggested that the pygidium assigned to *K. affinis* (Walcott, 1884) by Palmer (1965) should be tentatively assigned to *Iddingsia robusta* (Walcott, 1884). Due to the poor nature of the preservation, the nomenclature of this pygidium is left open. Palmer in Saltzman et al. (2004) also identified *Kindbladia* sp. from ICS1440, which is at the same level as USNM 44301 from which the poorly preserved pygidium was recovered.

Iddingsia cf. *I. intermedia* Palmer, 1965

Figure 13

1965 *Iddingsia intermedia* Palmer, p. 36, pl. 2, figs. 5–8.

Holotype.—USNM 141525 cranidium, from the Dunderberg Shale, McGill, Nevada, USA.

Occurrence.—Nounan Formation (*Dunderbergia* Biozone), Smithfield Canyon, Utah (see Appendix).

Remarks.—A single, partial cranidium and two librigenae match the specimens illustrated by Palmer (1965) in their cranidial convexity, granulation, glabellar shape, and glabellar furrows; however, the frontal area is mostly absent, preventing accurate identification. The two fragmentary librigenae are also similar to the specimen illustrated by Palmer (1965, pl. 2, fig. 5),

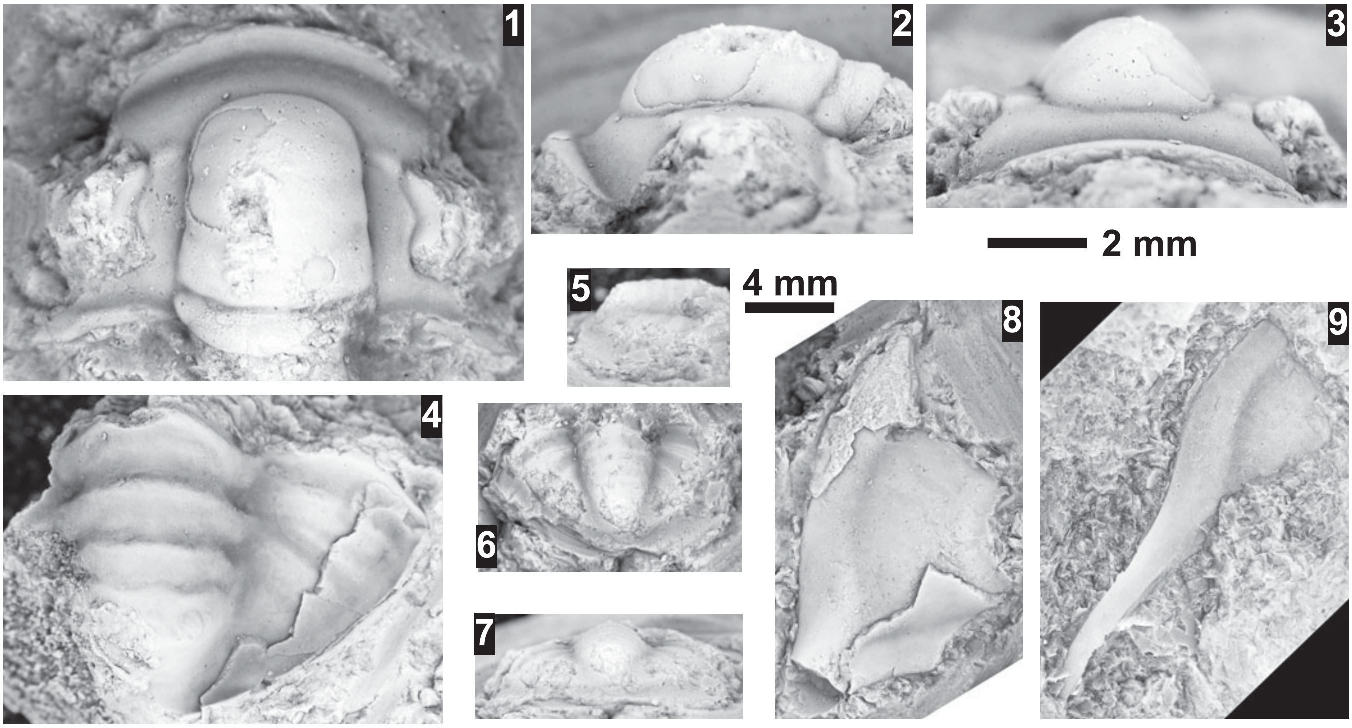

Figure 11. Trilobites from the *Elvinia* Biozone, Steptoean Stage, St. Charles Formation, Smithfield Canyon, Utah. All specimens are from USNM loc. 44301. (**1–3**) *Pseudosaratogia* sp. indet. partially exfoliated cranidium USNM 775657: (**1**) dorsal view; (**2**) lateral view; (**3**) anterior view. (**4**) *Elvinia* sp. indet, mostly exfoliated pygidium USNM 775661. (**5–9**) *Iddingsia* sp. indet.: (**5–7**) exfoliated pygidium USNM 775658: (**5**) lateral view; (**6**) dorsal view; (**7**) posterior vie; (**8**) mostly exfoliated librigena USNM 775660; (**9**) exfoliated librigena USNM 775659. (**1–3**) Specimens use the 2 mm scale bar; (**4–9**) specimens use the 4 mm scale bar.

including the absence of obvious granules on the genal areas. The specimens are left in open nomenclature due to the fragmentary nature of the specimens. This species was found in the upper half of the *Dunderbergia* Biozone (Palmer, 1965).

Genus *Pseudosaratogia* Wilson, 1951

Type species.—*Pseudosaratogia magna* Wilson, 1951, Gatesburg Formation, Pennsylvania (by original designation).

Pseudosaratogia sp. indet.
Figure 11.1–11.3

2022 *Pseudosaratogia leptogranulata* Cothren et al., fig. 2.1.

Occurrence.—St. Charles Formation (*Elvinia* Biozone), Smithfield Canyon, Utah (see Appendix).

Remarks.—A single well-preserved cranidium from USMN loc. 44301 and one poorly preserved cranidium from USNM loc. 44300 were recovered. These cranidia are similar to *Pseudosaratogia leptogranulata* Palmer, 1960, but the latter differs in possessing a longer and wider preglabellar area, a less-curved anterior border, a more-tapered glabella, and more-pronounced lateral glabellar furrows. The difference in glabellar tapering may be the result of ontogeny with the specimen from USMN loc. 44301 having a length of 6.7 mm versus the type specimen having a length of 11.3 mm.

Family Pterocephaliidae Kobayashi, 1935
Subfamily Housiinae Hupé, 1953
Genus *Housia* Walcott, 1916b

Type species.—*Dolichometopus* (*Housia*) *varro* Walcott, 1916b, Orr Formation, House Range, Utah.

Housia ovata Palmer, 1960
Figure 14

1960 *Housia ovata* Palmer, p. 75, pl. 7, figs. 1–7, 9.
1965 *Housia ovata*; Palmer, p. 65, pl. 12, figs. 8–11.

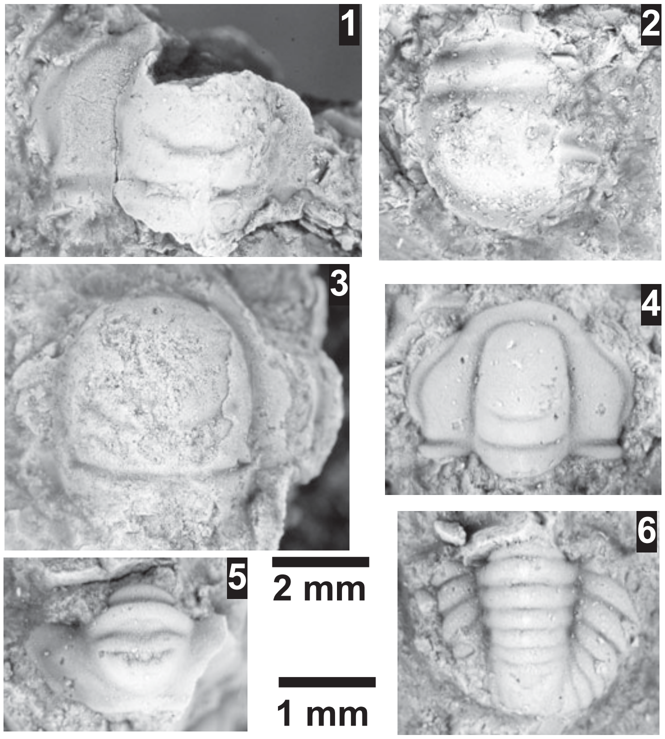

Figure 12. Trilobites from the *Elvinia* Biozone, Steptoean Stage, St. Charles Formation, Smithfield Canyon, Utah. All specimens are from USNM loc. 44301. (**1–5**) *Irvingella* cf. *I. flohri* Resser, 1942: (**1**) exfoliated partial cranidium USNM 775663; (**2**) pygidial axis USNM 775665; (**3**) mostly exfoliated cranidium USNM 775664; (**4**) small testate cranidium USNM 775666; (**5**) small testate pygidium USNM 775667. (**6**) *Cliffia* sp. indet., testate pygidium USNM 775668. (**1–3**) Specimens use the 2 mm scale bar; (**4–6**) specimens use the 1 mm scale bar.

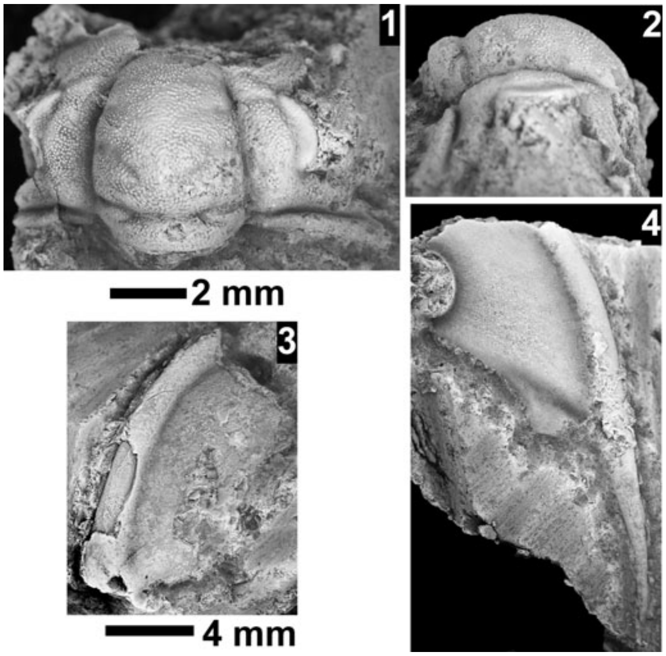

Figure 13. *Iddingsia* cf. *I. intermedia* Palmer, 1965 from the *Dunderbergia* Biozone, Steptoean Stage, Nounan Formation, Smithfield Canyon, Utah. All specimens are from USNM loc. 44298. (**1, 2**) Testate cranidium USNM 775692: (**1**) dorsal view; (**2**) lateral view. (**3**) Mostly testate partial librigena USNM 7755574. (**4**) Mostly exfoliated librigena USNM 775581. (**1, 2**) Specimens use the 2 mm scale bar; (**3, 4**) specimens use the 4 mm scale bar.

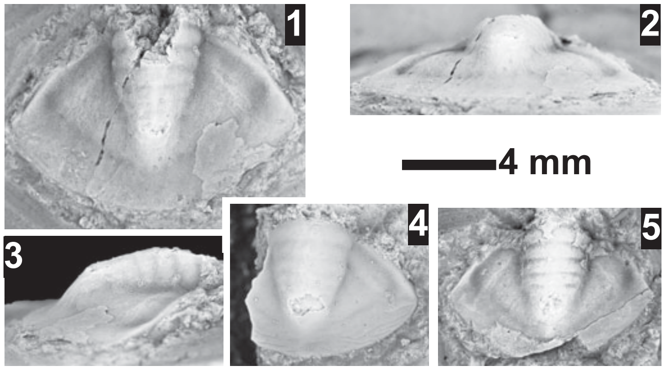

Figure 14. *Housia ovata* Palmer, 1965 from the *Elvinia* Biozone, Steptoean Stage, St. Charles Formation, Smithfield Canyon, Utah. All specimens are from USNM loc. 44299. (**1–3**) Exfoliated pygidium USNM 775684: (**1**) dorsal view; (**2**) posterior view; (**3**) lateral view. (**4**) Testate pygidium USNM 775686. (**5**) Exfoliated pygidium USNM 775685.

2005 *Housia ovata*; Lee and Chatterton, pl. 7, figs. 1, 2, 5, 9.
2022 *Housia ovata*; Cothren et al., fig. 2.5.

Holotype.—USNM 141678 cranidium, from the Corset Springs Shale, Snake Range, Nevada, USA.

Occurrence.—St. Charles Formation (*Elvinia* Biozone), Smithfield Canyon, Utah (see Appendix); Dunderberg Formation and Corset Springs Shale (*Elvinia* Biozone), Nevada (Palmer, 1965).

Remarks.—Only pygidia were found. This species was found in the lower part of the *Elvinia* Biozone in several sections (Palmer, 1965). This species was also reported by Saltzman et al. (2004) from loc. ICS-1438 at Smithfield Canyon.

Genus *Tumicephalus* Palmer, 1965

Type species.—*Tumicephalus depressus* Palmer, 1965 from the Dunderberg Shale, Utah, USA.

Remarks.—Palmer (1965) had questionably assigned *Tumicephalus* to the subfamily Housiinae. A phylogenetic study by Hopkins (2011) verified the genus's placement within the subfamily.

Tumicephalus depressus Palmer, 1965
Figure 15

1965 *Tumicephalus depressus* Palmer, p. 90, pl. 13, figs. 19–23.

Holotype.—USNM 141705 cranidium from the Hicks Formation, Deep Creek Range, Utah, USA.

Occurrence.—Nounan Formation (*Aphelaspis* Biozone), Smithfield Canyon, Utah (see Appendix); Dunderberg Formation, Lincoln Peak Formation, Hicks Formation, and Johns Wash Limestone (*Dicanthopyge* Biozone), Utah and Nevada (Palmer, 1965).

Remarks.—These specimens are typically small in the collections but do not represent a juvenile of the co-occurring *Aphelaspis*. The specimens have an upturned anterior border with a stronger curvature, swollen preglabellar area, and dorsally sloped intraocular area from the glabella to the

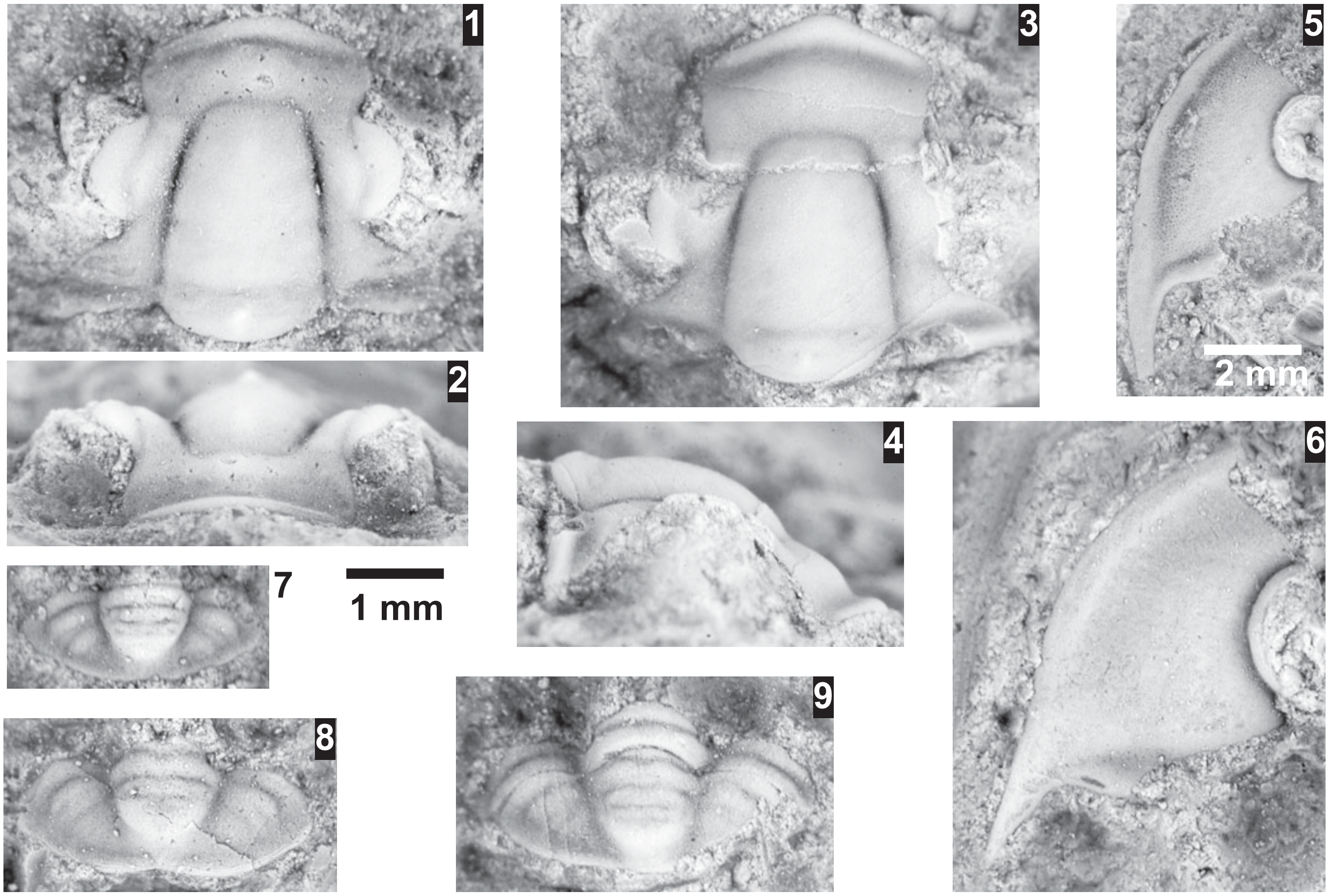

Figure 15. *Tumicephalus depressus* Palmer, 1965 from the *Prehousia* Biozone, Steptoean Stage, upper Nounan Formation, Smithfield Canyon, Utah. All specimens are from 44293 unless otherwise mentioned. (**1, 2**) Exfoliated cranidium USNM 775653: (**1**) dorsal view; (**2**) anterior view. (**3, 4**) Partially testate cranidium USNM 775651: (**3**) dorsal view; (**4**) lateral view. (**5**) Testate librigena USNM 775656 (loc. USNM 44291). (**6**) Exfoliated librigena USNM 775650. (**7**) Exfoliated pygidium USNM 775654. (**8**) Mostly exfoliated pygidium USNM 775655 (loc. USNM 44291). (**9**) Testate pygidium and thoracic segment USNM 775652. (**1–4, 6–9**) Specimens use the 1 mm scale bar; (**5**) specimen uses the 2 mm scale bar.

palpebral lobe unlike smaller specimens of *Aphelaspis*. Palmer (1965, p. 90) stated that this species is commonly found in the *Dicanthopyge* Biozone; however, its occurrence with *Aphelaspis* cf. *A. arsoides* and below *A. subditus* either extends the range of *T. depressus* into the *Aphelaspis* Biozone or extends the range of *A. suditus* into the *Dicanthopyge* Biozone. Palmer (1965) included *Aphelaspis tumifrons* Resser, 1938 into *Tumicephalus*. Rasetti (1965) reported *A. tumifrons* commonly from the same horizons as *A. arsoides* in the southern Appalachians; at Smithfield Canyon, it occurs with *Aphelaspis* cf. *A. arsoides*.

Superfamily Uncertain
Family Catillicephalidae Raymond, 1938
Genus *Welleraspis* Kobayashi, 1935

Type species.—*Solenopleura jerseyensis* Weller, 1899, upper Cambrian, New Jersey (by original designation).

Welleraspis? sp. indet.
Figure 16.13

Occurrence.—Nounan Formation (*Crepicephalus* Biozone), Smithfield Canyon, Utah (see Appendix).

Remarks.—Only a few small cranidia were found, and without associated pygidia the genus cannot be firmly assigned.

Family Cheilocephalidae Shaw, 1956
Genus *Cheilocephalus* Berkey, 1898

Type species.—*Cheilocephalus saintcroixensis* Berkey, 1898, St. Lawrence Formation, Minnesota (by original designation).

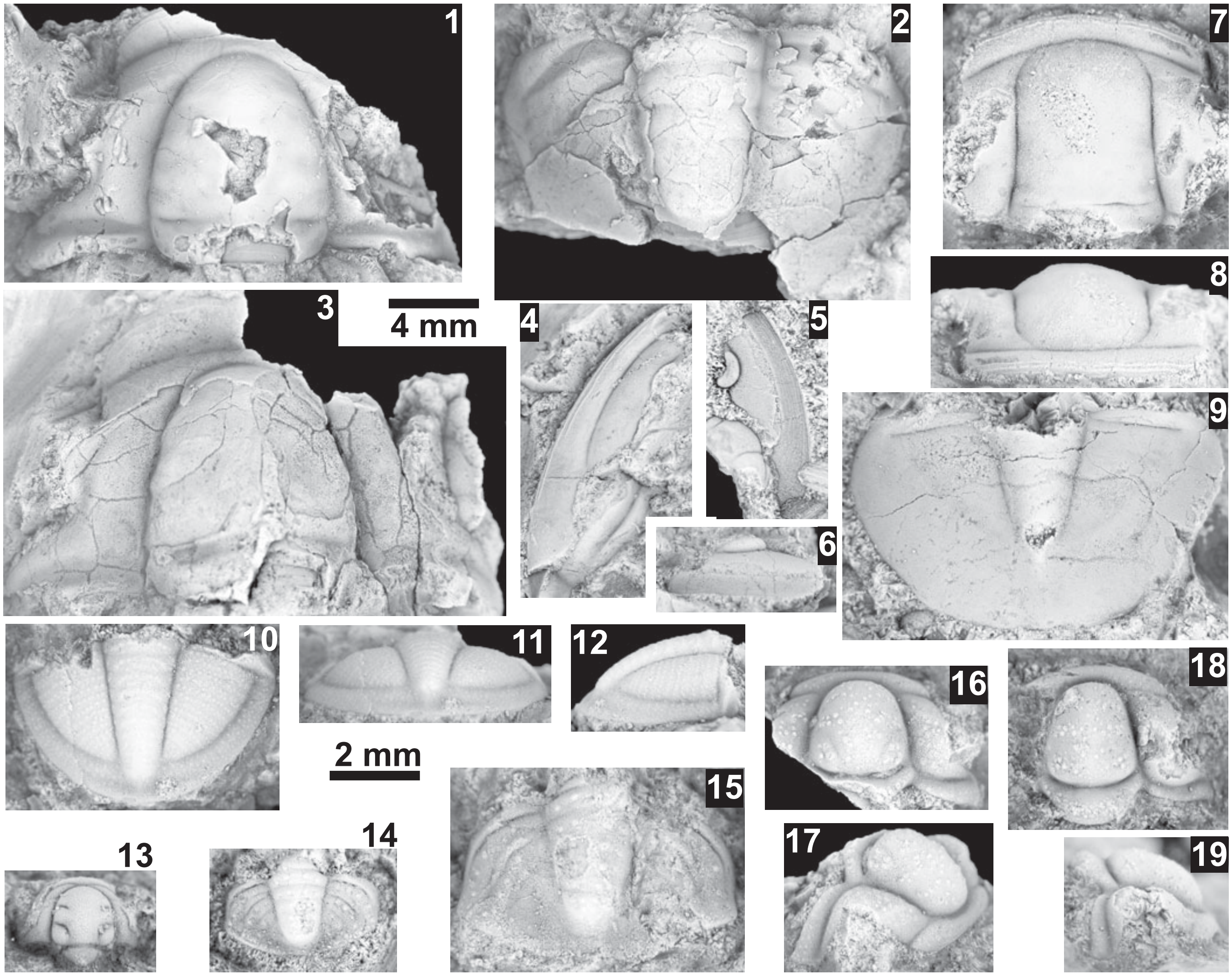

Figure 16. Trilobites from the *Crepicephalus* Biozone, Marjuman Stage, Nounan Formation, Smithfield Canyon, Utah. All specimens are from USNM loc. 44290. (**1–6**) *Coosina* cf. *C. amage* (Walcott, 1916b): (**1**) partially testate cranidium USNM 775624; (**2**) partially testate pygidium USNM 775623; (**3**) partially testate cranidium USNM 775622; (**4**) librigena USNM 775575; (**5, 6**) librigena with ocular region preserved USNM 775588, inverted photograph: (**5**) dorsal view; (**6**) lateral view. (**7–9**) "*Coosella*" *berryi* (Lochman, 1940): (**7, 8**) exfoliated cranidium USNM 775621: (**7**) dorsal view; (**8**) anterior view; (**9**) exfoliated pygidium USNM 775620. (**10–12**) *Blountia* sp. indet. exfoliated pygidium USNM 775619: (**10**) dorsal view; (**11**) posterior view; (**12**) lateral view. (**13**) *Welleraspis*? sp. indet. cranidium USNM 775629. (**14–20**) *Genevievalla* sp. indet.: (**14**) testate pygidium USNM 775626; (**15**) partially testate pygidium USNM 775625; (**16, 17**) exfoliated cranidium USNM 775627: (**16**) dorsal view; (**17**) oblique view; (**18, 19**) partially testate cranidium USNM 775628: (**18**) dorsal view; (**19**) lateral view. (**1–6**) Specimens use the 4 mm scale bar; (**7–19**) specimens use the 2 mm scale bar.

Cheilocephalus sp. indet.
Figure 17

2022 *Cheilocephalus* sp., Cothren et al., fig. 2.13.

Occurrence.—Nounan Formation (*Prehousia* Biozone), Smithfield Canyon, Utah (see Appendix).

Remarks.—The pygidium found from USNM loc. 44296 has a wide border that is slightly upturned at the edge, a high profile with a steep descent from the axis to the anterior border, and no evidence of the pleural furrows crossing the border. In these features, the pygidium is similar to *Cheilocephalus brachyops* Palmer, 1965, *C. brevilobus* (Walcott, 1916b), and *C. granulosus* Palmer, 1965. These taxa occur in the *Aphelaspis* to *Elvinia* biozones according to Palmer; thus, its occurrence here in the *Prehousia* Biozone is possible. Palmer in Saltzman et al. (2004) reported *C. granulosus* from loc. ICS-1437 at Smithfield Canyon. This species is known from the *Dicanthopyge* to *Dunderbergia* biozones in Nevada (Palmer, 1965).

Family Crepicephalidae Kobayashi, 1935
Genus *Coosella* Lochman, 1936

Type species.—*Coosella prolifica* Lochman, 1936, Bonneterre Dolomite, Missouri (by original designation).

"*Coosella*" *berryi* (Lochman, 1940)
Figure 16.7–16.9

1940 *Prochuangia*? *berryi* Lochman (part), p. 39, pl. 4, figs. 18–20 (only).
1951 *Genevievalla campbellina* Tasch (part), p. 292, pl. 46, figs. 17, 18 (only).
1960 *Genevievalla campbellina*; Robison, p. 25, pl. 2, fig. 8.
1965 Undetermined Pygidium No. 2 Rasetti, p. 113, pl. 6, figs. 20, 21.
2022 *Coosia* sp., Cothren et al., fig. 2.14.

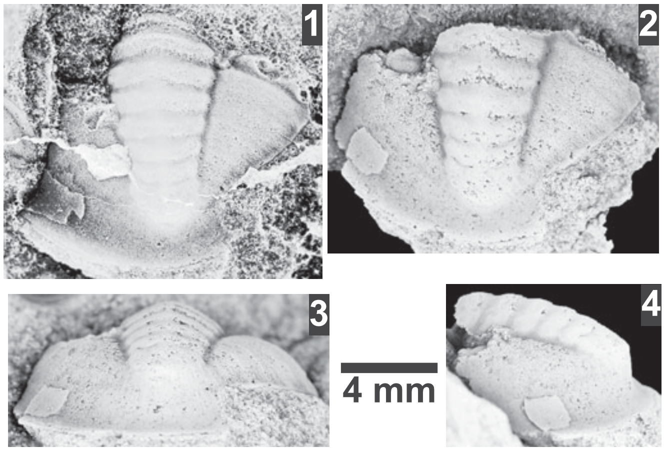

Figure 17. *Cheilocephalus* sp. from the *Prehousia* Biozone, Steptoean Stage, Nounan Formation, Smithfield Canyon, Utah. All specimens are from USNM loc. 44296. (**1–4**) Exfoliated pygidium USNM 775698: (**1**) dorsal counterpart inverted photograph; (**2**) dorsal view; (**3**) posterior view; (**4**) lateral view.

Holotype.—USNM 98750 cranidium from the Bonneterre Dolomite, Missouri, USA.

Occurrence.—Nounan Formation (*Crepicephalus* Biozone), Smithfield Canyon, Utah (see Appendix); Bonneterre Dolomite (*Cedaria* Biozone), near Jaydee, Missouri (Lochman, 1940); Nolinchuky Formation (*Crepicephalus* Biozone), Rogersville, Virginia (Rasetti, 1965); Warrior Formation (*Cedaria* to *Crepicephalus* biozones?), Pennsylvania (Tasch, 1951); Orr Formation (upper *Cedaria* to lower *Crepicephalus* biozones), House Range, Utah (Robison, 1960; Eby, 1981).

Remarks.—A cranidium and a few pygidia were found at USNM loc. 44290. These samples are very similar to specimens reported by Eby (1981) from the upper *Cedaria* to lower *Crepicephalus* biozones, House Range, Utah. Eby, in his dissertation, reported 25 cranidia and 56 pygidia of *Prochuangia*? *berryi* under a new genus, which has yet to be formally established. These sclerite associations illustrate that this species does not belong to *Prochuangia* as suggested by Lochman (1940) or *Genevievalla* as reported by Tasch (1951) and Robison (1960) on the basis of cranidial and/or pygidial differences. Rasetti (1965, p. 114) noted that the pygidia from Virginia are similar to *Coosia* or a related taxon, of which the authors agree. However, the cranidia are unlike any of the *Coosia* or related taxa in its nearly parallel-sided glabella that extends to the anterior border furrow. At present, this species is placed into "*Coosella*" on the basis of the pygidial characteristics, but this placement is problematic, and it probably belongs to a new genus. Specimens reported here are not complete or abundant enough to justify proposing a new generic name.

Genus *Coosia* Walcott, 1911

Type species.—*Coosia superba* Walcott, 1911, Conasauga Formation, Alabama (by original designation).

Coosia? sp.
Figure 18.3, 18.4

Occurrence.—Nounan Formation (*Cedaria* Biozone), Smithfield Canyon, Utah (see Appendix).

Remarks.—These small cranidia could belong to meraspides of any related taxon to *Coosia*. No pygidia can be associated with the cranidia.

Genus *Coosina* Rasetti, 1956

Type species.—*Maryvillia ariston* Walcott, 1916b, Maryville Formation, Tennessee (by original designation).

Coosina cf. *C. amage* (Walcott, 1916b)
Figure 16.1–16.6

1916b *Blountina amage* Walcott, p. 398, pl. 64, fig. 3, 3a.
1916b *Blountina alethas* Walcott (part), p. 397, pl. 64, fig. 1b, c (only).
1938 *Coosella amage*; Resser, p. 70, pl. 13, figs. 12, 13.
1965 *Coosina amage*; Rasetti, 1965, p. 50, pl. 7, figs. 14–22.

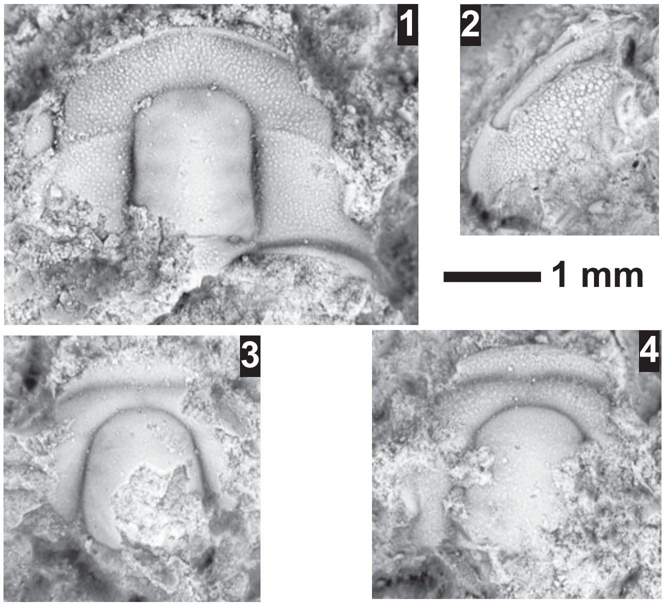

Figure 18. Trilobites from the *Cedaria* Biozone, Marjuman Stage, Nounan Formation, Smithfield Canyon, Utah. All specimens are from USNM loc. 44289. (**1**) *Glaphyraspis* sp. indet. testate cranidium USNM 775630. (**2**) *Menomonia* cf. *M. tuberculata* (Resser, 1942) testate librigena USNM 775633. (**3, 4**) *Coosia*? sp. indet.: (**3**) exfoliated partial cranidium USNM 775632; (**4**) testate partial cranidium USNM 775631.

Holotype.—USNM 62824, cranidium, from the Nolichucky Formation, near Knoxville (USNM loc. 107), Tennessee, USA.

Occurrence.—Nounan Formation (*Crepicephalus* Biozone), Smithfield Canyon, Utah (see Appendix)

Remarks.—These specimens are incompletely preserved and appear to have a shorter preglabellar area when compared to Rasetti (1965). As a result, these specimens are assigned to *Coosina* cf. *C. amage* (Walcott, 1916b).

Family Idahoiidae Lochman, 1956
Genus *Saratogia* Walcott, 1916a

Type species.—*Conocephalites calciferous* Walcott, 1879 from the Hoyt Limestone, New York, (by original designation).

Subgenus *Saratogia* (*Idahoia*) Walcott, 1924

Type species.—*Idahoia serapio* Walcott, 1924 from the Ovid Formation, Idaho, (by original designation).

Saratogia (*Idahoia*) aff. *S.* (*I.*) *fria* Lochman and Hu, 1959
Figure 19.1–19.10

?1962 *Saratogia fria* Lochman and Hu, 1959, Bell and Ellinwood, p. 394, pl. 53, figs. 19, 20 [non figs. 13–18, 21].

Occurrence.—St. Charles Formation (*Taenicephalus* Biozone), Smithfield Canyon, Utah (see Appendix).

Remarks.—The specimens from Smithfield Canyon are similar to those of *Saratogia* (*I.*) *fria* from the St. Charles Formation of Idaho (Lochman and Hu, 1959) in glabellar shape, relative length of the preglabellar area, position of palpebral lobes, and angle of anterior suture. However, the type material (Lochman and Hu, 1959, pl. 59, figs. 1–11; Ludvigsen and Westrop, 1983, pl. 9, fig. 4) possesses a long occipital spine, which is lacking in the specimens from Smithfield Canyon, which possess only a small occipital node. Bell and Ellinwood (1962) figured two specimens (pl. 53, figs. 19, 20) from Texas without occipital spine or node that they assign to *S. fria*. They mention all of the cranidial features are the same other than the spine, but one of the key features they discussed for *S. fria* from Texas is the presence of coarse granules on the "occipital ring, occipital spine, posterior limbs, and preoccipital glabellar lobes…" (Bell and Ellinwood, 1962, p. 394). These granules are not apparent on the type, the Texas (Ludvigsen and Westrop, 1983, pl. 9, fig. 5), or the Smithfield material, and the forms without an occipital spine may represent the same species as the Smithfield material.

The Smithfield material is left in open nomenclature due to the lack of well-preserved material.

Genus *Wilbernia* Walcott, 1924

Type species.—*Ptychoparia pero* Walcott, 1890 from the Wilberns Formation, Texas (by original designation).

Wilbernia aff. *W. expansa* Frederickson, 1949
Figure 20.4–20.11

Occurrence.—St. Charles Formation (*Ellipsocephaloides* Biozone), Smithfield Canyon, Utah (see Appendix).

Remarks.—The single cranidium from the St. Charles Formation is similar to *Wilbernia expansa* in its short frontal area, concave anterior border, wide intraocular area of the fixigena, and slightly tapered glabella. A difference between specimens illustrated by Frederickson (1949, pl. 72, figs. 13–16) and those illustrated by Bell and Ellinwood (1962, pl. 54, figs. 11, 12) is the shorter (sag.) anterior border in the latter. A co-occurring librigena (Fig. 20.5) also has a convex border and is also assigned to *Wilbernia* aff. *W. expansa*. Co-occurring pygidia (Figure 20.6–20.9) are similar to pygidia assigned to either *Wilbernia* (Bell et al., 1952, pl. 34, fig. 4, 4e; Bell and Ellinwood, 1962, pl. 54, fig. 20; Westrop, 1986, pl. 12, figs. 5, 10, 13) or some *Levisella* Ulrich in Rasetti, 1944 (Ludvigsen et al., 1989, pl. 6., fig. 13, pl. 7, figs. 7, 10, pl. 8, fig. 12). These specimens are left in open nomenclature due to the incomplete cranidia and limited specimens.

Wilbernia cf. *W. explanata* (Whitfield, 1880)
Figure 19.11–19.16

1880 *Conocephalites* (*Ptychaspis*?) *explanatus* Whitfield, p. 48.

1986 *Wilbernia explanata*, Westrop, p. 43, pl. 12, figs. 1–10, pl. 13, figs. 10–12 (see for further synonymy).

Holotype.—Incomplete cranidium from the Loan Rock Formation, Hudson, Wisconsin.

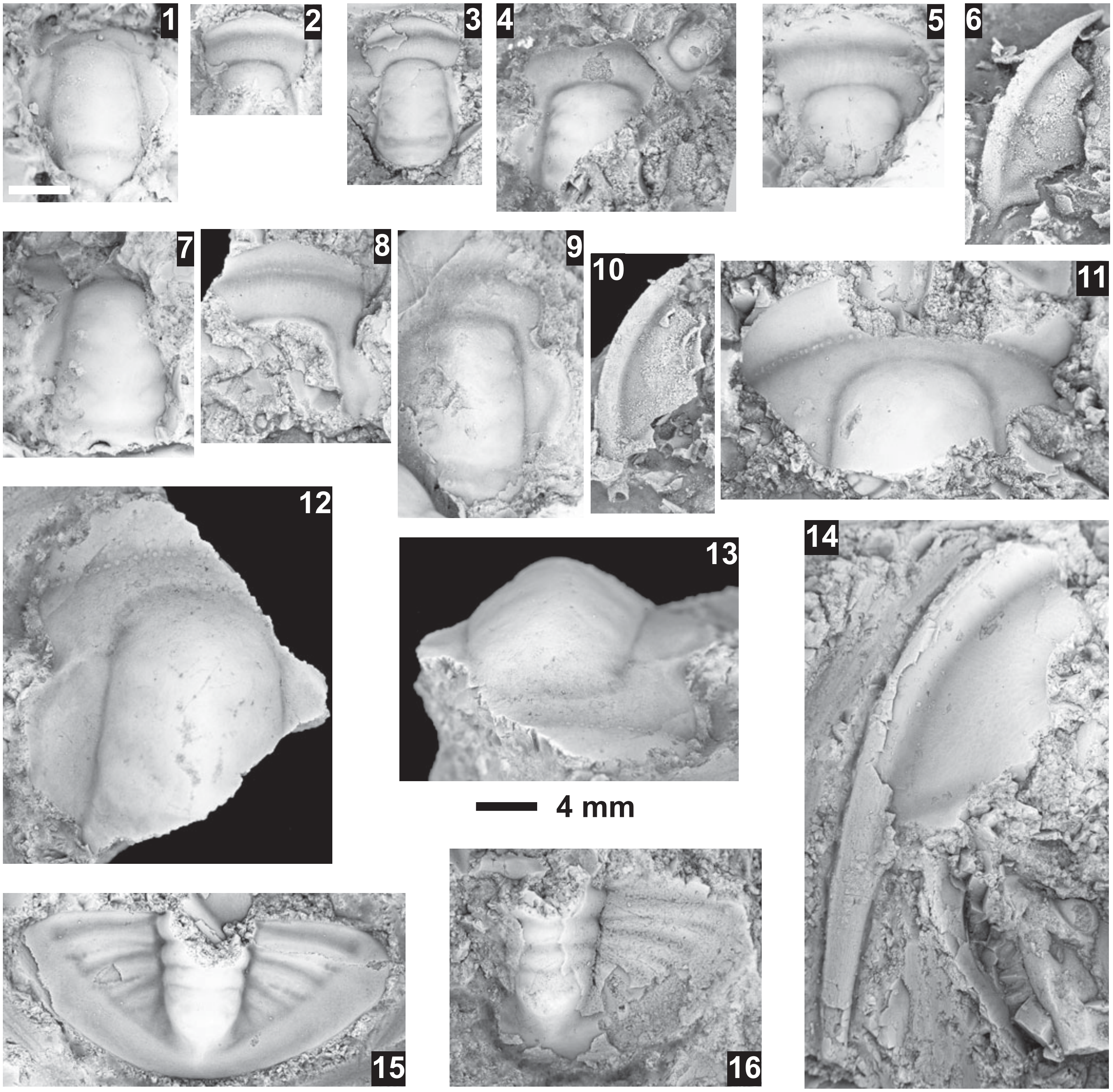

Figure 19. Trilobites from the Sunwaptan Stage, St. Charles Formation, Smithfield Canyon, Utah. All specimens are from USNM loc. 44304, exfoliated or mostly exfoliated. (**1–10**) *Saratogia* (*Idahoia*) aff. *S.* (*I.*) *fria* Lochman and Hu, 1959: (**1**) small partial cranidium USNM 781838; (**2**) cranidium USNM 781837; (**3**) exfoliated cranidium USNM 781826; (**4**) cranidia USNM 781824 and 781825 (upper right); (**5**) partial cranidium USNM 781836; (**6**) silicified librigena USNM 781827; (**7**) cranidium USNM 781835; (**8**) cranidium USNM 781833; (**9**) exfoliated partial cranidium USNM 781839; (**10**) silicified librigena USNM 781828. (**11–16**) *Wilbernia* cf. *W. explanata* (Whitfield, 1880): (**11**) partial cranidium USNM 781832; (**12, 13**) cranidium USNM 781829: (**12**) dorsal view; (**13**) anterior view; (**14**) mostly exfoliated librigena USNM 781834; (**15**) testate pygidium USNM 781831; (**16**) partial pygidium USNM 781830. (**1**) White scale bar = 2 mm; (**2–16**) specimens use the 4 mm scale bar.

Occurrence.—St. Charles Formation (*Ellipsocephaloides* Biozone), Smithfield Canyon, Utah (see Appendix).

Remarks.—The specimens from the St. Charles Formation are similar to *Wilbernia explanata* in their long frontal area, relatively flat anterior border, wide intraocular area of the fixigena, slightly tapered glabella, and wide pygidium. Most of the specimens reported here are fragmented, but they vary in the length of the preglabellar area, primarily on the basis of specimen size as suggested by Westrop (1986, p. 43). An additional difference between specimens illustrated by Westrop (1986, pl. 12, fig. 5) and herein is the rounded terminal piece of the pygidial axis versus the pointed termination of the specimens illustrated herein. The specimens are left in open nomenclature due to the incomplete cranidia and the rounded terminal piece of the pygidial axis.

Wilbernia aff. *W. pero* (Walcott, 1890)
Figure 20.1–20.3

Occurrence.—St. Charles Formation (*Ellipsocephaloides* Biozone), Smithfield Canyon, Utah (see Appendix).

Remarks.—The three cranidia from the St. Charles Formation are similar to *Wilbernia pero* in their short preglabellar area, narrow intraocular area of the fixigena, and nearly parallel-sided glabella. Most of the sclerites reported here are fragmented but differ from previously illustrated specimens (Bell et al., 1952, pl. 34, fig. 5a–c; Bell and Ellinwood, 1962, pl. 54, figs. 19, 21; Grant, 1962, pl.139, fig. 8a–c; Westrop, 1986, pl. 13, figs. 1–3) in possessing a less convex anterior border and a less constricted (hourglass shape) glabella with a strongly rounded frontal lobe similar to those illustrated by Frederickson (1949, pl. 72, figs. 7–9). These specimens are similar to other species of *Wilbernia* and specifically *W. pero* but are different enough that they may represent a new species. The specimens are left in open nomenclature until additional material can be found.

Family Kingstoniidae Kobayashi, 1933
Subfamily Kingstoniinae Kobayashi, 1933
Genus *Kingstonia* Walcott, 1924

Type species.—*Kingstonia apion* Walcott, 1924, Maryville Formation, Tennessee (by original designation).

Kingstonia smithfieldensis new species
Figure 21

2022 *Kingstonia* sp., Cothren et al., fig. 2.16, 2.17.

Holotype.—Cranidium USMN 775572 from the Nounan Formation, Smithfield Canyon, Utah (USMN loc.44289).

Paratypes.—Specimens USMN 775573–775618 from the Nounan Formation, Smithfield Canyon, Utah (USMN loc.44289).

Diagnosis.—Cranidia with tapering glabella with an expanding frontal lobe, well-defined axial furrows, and occipital ring furrow and pygidium half-moon shaped and well-defined anterior pleural furrow. Lateral glabellar furrows, axial ring furrows, and pleural furrows not defined in ventral surface.

Occurrence.—Nounan Formation (*Crepicephalus* Biozone), Smithfield Canyon, Utah (see Appendix).

Description.—Cranidium of small to moderate size, length 3.6 ± 1.2 mm (N = 32); subtriangular, moderate convexity (sag. and trans.); anterior margin moderately and evenly curved, not arched dorsally; posterior margin (excluding occipital ring) directed laterally. Anterior branches of facial

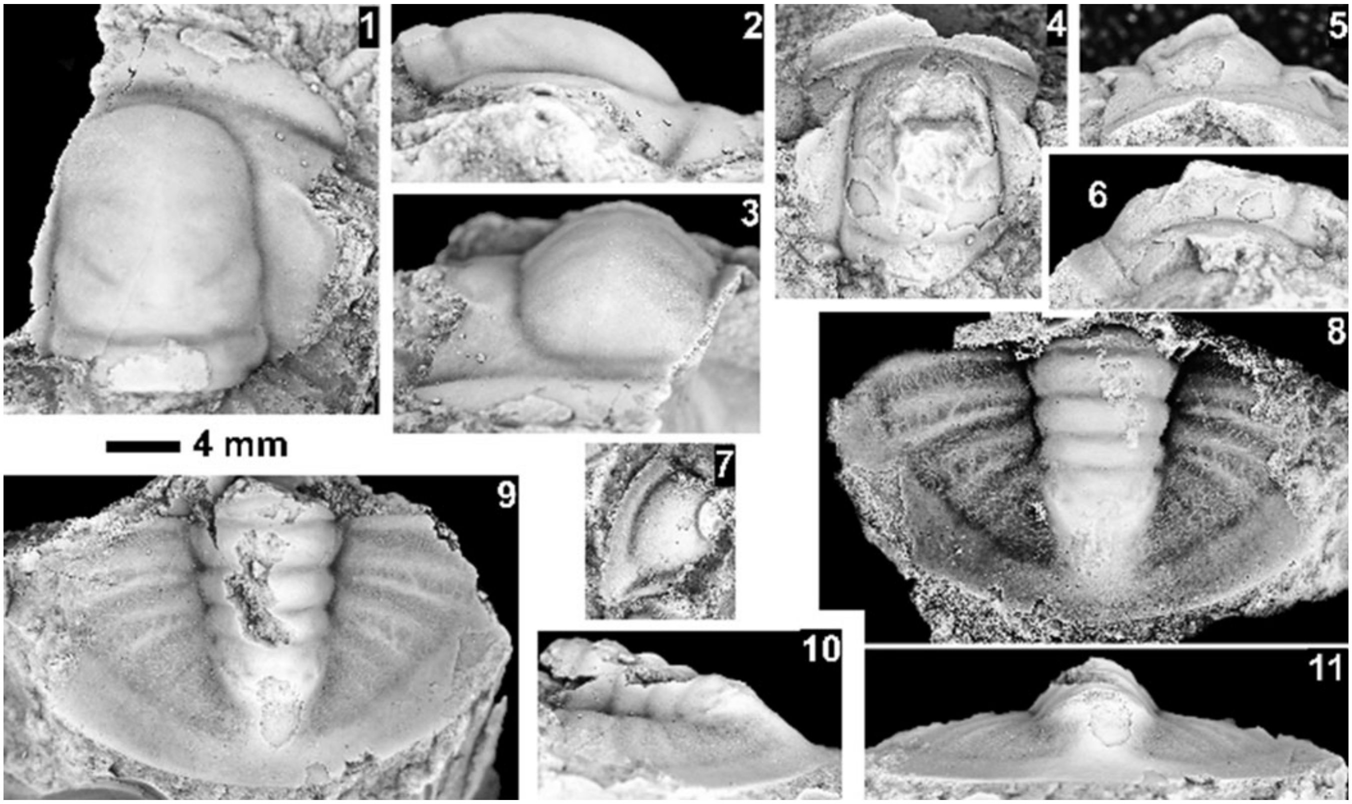

Figure 20. *Wilbernia* species from the Sunwaptan Stage, St. Charles Formation, Smithfield Canyon, Utah. All specimens are from USNM loc. 44303. (**1–3**) *Wilbernia* aff. *W. pero* (Whitfield, 1880), partial, exfoliated cranidium USNM 781843: (**1**) dorsal view; (**2**) lateral view; (**3**) anterior view. (**4–11**) *Wilbernia* aff. *W. expansa* Frederickson, 1949: (**4–6**) mostly testate cranidium USNM 781841: (**4**) dorsal view; (**5**) anterior view; (**6**) lateral view; (**7**) exfoliated librigena USNM 781840; (**8–11**) mostly testate pygidium USNM 781842: (**8**) inverted counterpart dorsal showing ornamentation; (**9**) dorsal view; (**10**) lateral view; (**11**) posterior view.

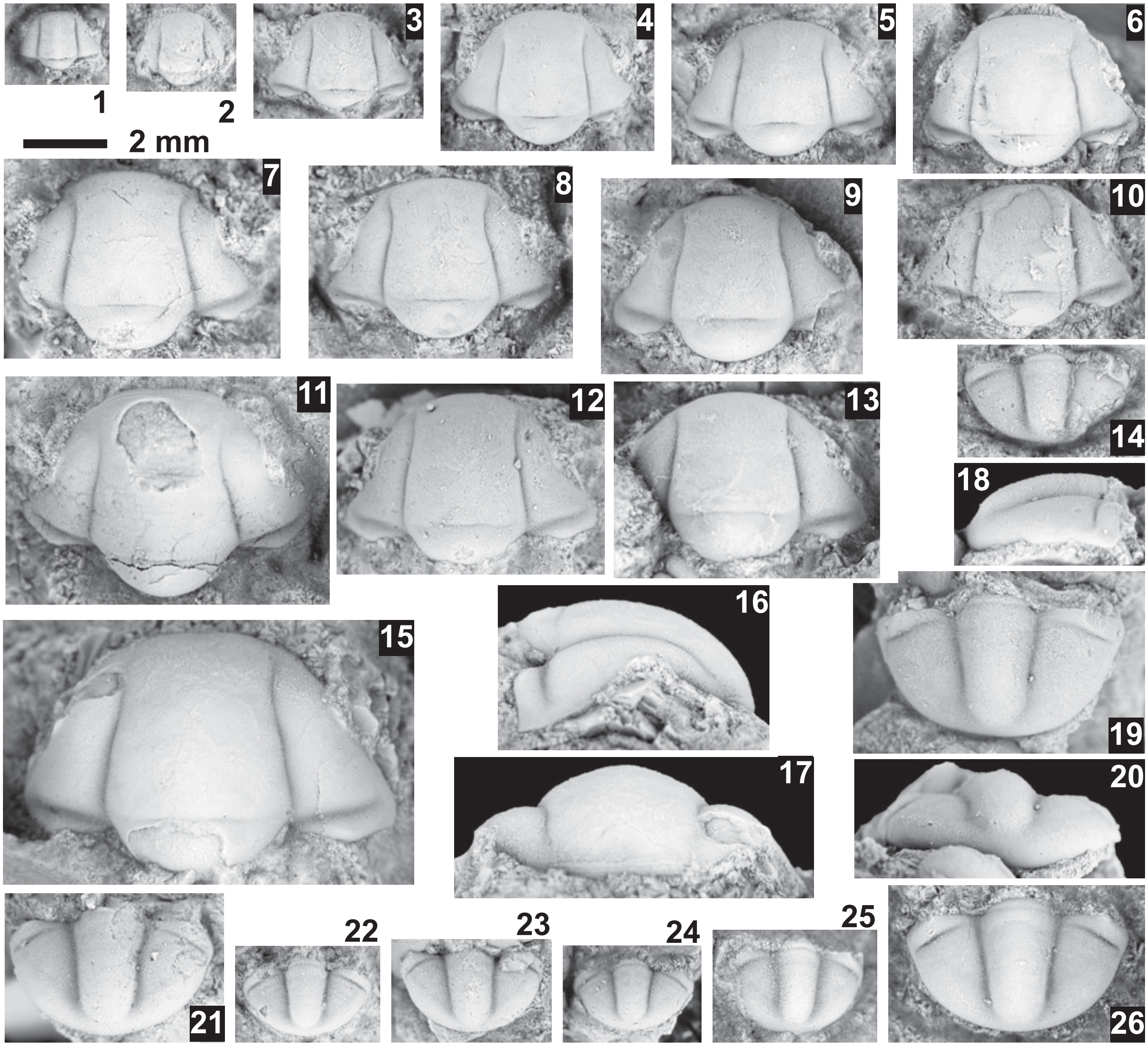

Figure 21. *Kingstonia smithfieldensis* n. sp. from the Marjuman Stage, Nounan Formation, Smithfield Canyon, Utah. All specimens are from USNM loc. 44290, paratypes unless otherwise mentioned, testate or mostly testate, and in dorsal view unless specified. (**1**) Small cranidium USNM 775608. (**2**) Cranidium USNM 775596. (**3**) Cranidium USNM 775599. (**4**) Cranidium USNM 775603. (**5**) Cranidium USNM 775592. (**6**) Cranidium USNM 775591. (**7**) Cranidium USNM 775590. (**8**) Cranidium USNM 775584. (**9**) Cranidium USNM 775617. (**10**) Cranidium USNM 775600. (**11**) Cranidium USNM 775582. (**12**) Cranidium USNM 775614. (**13**) Cranidium USNM 775587. (**14**) Pygidium USNM 775616, right side exfoliated. (**15–17**) Holotype cranidium USNM 775572: (**15**) dorsal view; (**16**) anterior view; (**17**) lateral view. (**18–20**) Pygidium USNM 775577: (**18**) lateral view; (**19**) dorsal view; (**20**) posterior view. (**21**) Pygidium USNM 775618. (**22**) Pygidium USNM 775601. (**23**) Pygidium USNM 775602. (**24**) Pygidium USNM 775610. (**25**) Pygidium USNM 775576. (**26**) Pygidium USNM 775580.

sutures convergent by 38 ± 7° to anterior border; posterior branches moderately divergent at 56 ± 8°. Glabella elongate, hourglass shaped, length 100 ± 1% cranidial length; width 50 ± 2% cranidial width; slightly tapered, width at anterior end 84 ± 4% of posterior glabellar width; low convexity (sag. and trans.); frontal lobe bluntly rounded. Axial furrows moderately deep, with constriction at the L4 anterior end at 81 ± 4% of glabellar width; preglabellar furrow very shallow. Lateral glabellar furrows effaced. Occipital ring not elevated above rest of glabella, moderately convex; length 22 ± 3% glabellar length; posterior margin moderately convex posteriorly, no occipital node. SO straight to very slightly curved posteriorly medially; deepest centrally, moderate depth, very shallow laterally. Preglabellar field absent. Anterior border very slightly convex, downsloping, length 0 ± 1% cranidial length, tapering laterally, no medial inbend or swelling. Anterior border furrow very shallow. Fixigena slightly convex, nearly level, anterior area downsloping anteriorly, width 27 ± 3% of posterior glabellar width. Palpebral lobes nearly straight, level, narrow, and moderately long, length 22 ± 3% glabellar length; anterior margin located transversely opposite of S3 or L4. Ocular ridge generally not defined, directed slightly posterolaterally from glabella at 56 ± 3° to sagittal axis. Posterior area of fixigena triangular, with strong anterolateral flexure laterally, terminated with rounded corner; length 38 ± 3% glabellar length; width 38 ± 3% glabella length.

Rostral plate, hypostome, librigenal, and thorax unknown.

Pygidium small to moderate length, length 2.6 ± 0.8 mm (N = 11); half-moon shaped, length 56 ± 3% width; margin smooth, anterior margin nearly straight and directed slightly posterolaterally; anterolateral corners sharply rounded, transversely opposite anterior portion of axis; no postaxial notch; moderately convex (sag.). Axis moderately tapered, mid-width 85 ± 3% anterior width, anterior width 35 ± 2% pygidial width; length 89 ± 1% pygidial length, extends to nearly posterior margin; possibly five or six axial rings, moderately convex; terminal piece small, rounded posteriorly; axial ring furrows shallow. Pleural regions convex, downsloping around margin; anteriormost pleural furrow narrow and moderately deep laterally, extending to near margin; other pleural furrows very shallow to absent. Border not defined.

Terrace lines on the cranidial anterior border and lateral and ventral margins of the librigenal border. Other surfaces may have a small punctuate pattern, but this may be the result of preservation. Exoskeleton relatively thick.

Etymology.—Named after the type locality in Smithfield Canyon.

Remarks.—Many aspects of this new species are similar to *Kingstonia inflata* Resser, 1938, including the cranidial outline, anterior and posterior cranidial border and furrows, exoskeleton thickness, and pygidial shape and furrows. However, unlike most representatives of *Kingstonia*, this species has well-defined cranidial and pygidial furrows and a relatively long (sag.) occipital ring. Also, by contrast is the apparent absence of lateral glabellar furrows and pygidial axial ring furrows and pleural/interpleural furrows on the internal molds of the sclerites (see Fig. 21.11, 21.25). Westrop (1992, p. 244) discussed a potential synapomorphy linking taxa in Kingstoniidae that consists of a very short (5–10% glabellar length—calculated from specimens illustrated by Eby, 1981) occipital ring that forms a transverse band that is depressed below the adjacent portions of the glabella. This unique narrow occipital ring occurs in *Kingstonia*, *Bynumia* Walcott, 1924, *Ankoura* Resser, 1938, and *Bynumina* Resser, 1942. Westrop (1992) tentatively included *Blountia* (Walcott, 1916b) and *Maryvillia* Walcott, 1916b into Kingstoniidae, which was further substantiated by Armstrong et al. (2020). The new species reported here clearly does not possess this synapomorphy, with an occipital ring nearly 20% glabellar length and occurring slightly at the same elevation as the adjacent glabellar lobes and the hourglass shape of the glabella.

Subfamily Blountiinae Lochman in Lochman and Duncan, 1944
Genus *Blountia* Walcott, 1916b

Type species.—*Blountia mimula* Walcott, 1916b, Maryville Formation, Tennessee (by original designation).

Blountia sp. indet.
Figure 16.10–16.12

2022 *Blountia* sp. Cothren et al., fig. 2.25.

Occurrence.—Nounan Formation (*Crepicephalus* Biozone), Smithfield Canyon, Utah (see Appendix).

Remarks.—A single pygidium was found that fits this genus well, but its granular surface ornamentation is unique. Eby (1981) reported similar pygidia from the upper *Cedaria* Biozone in the House Range, Utah.

Family Llanoaspididae Lochman in Lochman and Duncan, 1944
Genus *Genevievella* Lochman, 1936

Type species.—*Genevievella neunia* Lochman, 1936, Bonneterre Dolomite, Missouri (by original designation).

Genevievella sp. indet.
Figure 16.14–16.19

Occurrence.—Nounan Formation (*Crepicephalus* Biozone), Smithfield Canyon, Utah (see Appendix).

Remarks.—A few cranidia and pygidia were found at USNM loc. 44290. These samples are unlike the previously named species but are very similar to specimens reported by Eby (1981) from the upper *Cedaria* Biozone, House Range, Utah.

Family Loganellidae Rasetti in Moore, 1959
Genus *Noelaspis* Ludvigsen, Westrop, and Kindle, 1989

Type species.—*Noelaspis bilobata* Ludvigsen, Westrop, and Kindle, 1989 from the Shallow Bay Formation, western Newfoundland (by original designation).

Noelaspis? sp. indet.
Figure 22

Occurrence.—St. Charles Formation (*Taenicephalus* Biozone), Smithfield Canyon, Utah (see Appendix)

Remarks.—These specimens are most similar to *Noelaspis* in the placement and lengths of the palpebral lobes, glabellar furrows, lateral glabellar furrows, fixigenal width, frontal area, and pygidial outline. However, the specimens are questionably assigned to *Noelaspis* on the basis of the stronger rounded frontal lobe, narrower glabella, and strongly upsloping intraocular region of the fixigena. The associated hypostome is similar to the closely related *Orygmaspis* Resser, 1937 as illustrated by Ludvigsen et al. (1989, pl. 10, fig. 5).

Noelaspis has previously been reported from the *Beothuckia duomenta* fauna of Newfoundland, which is compared to the *Stigmacephalus oweni* fauna and *Ellipsocephaloides* Biozone of Alberta (Westrop, 1986, Ludvigsen et al., 1989).

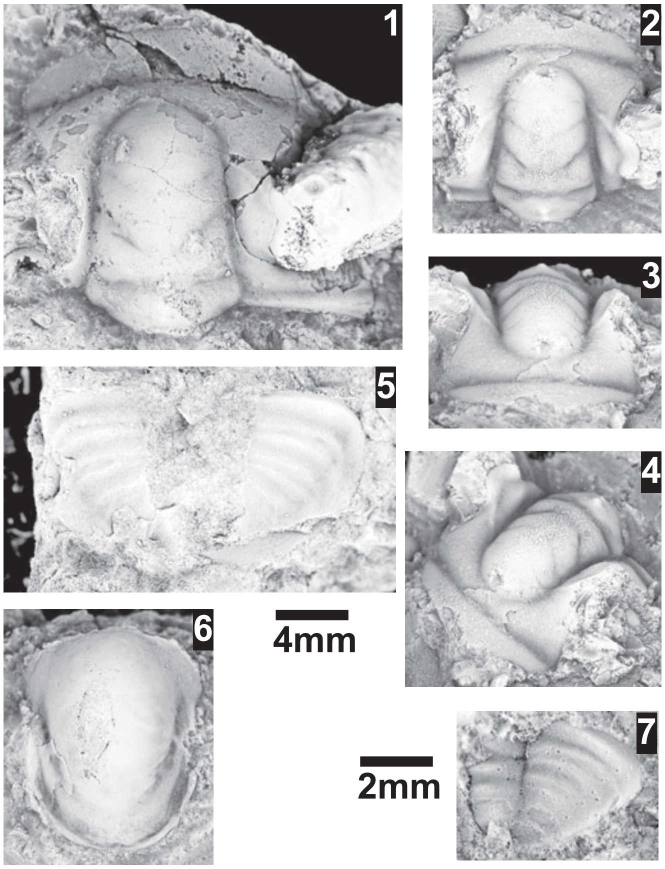

Figure 22. *Noelaspis*? sp. from the Sunwaptan Stage, St. Charles Formation, Smithfield Canyon, Utah. All specimens are from USNM loc. 44302. (**1**) Exfoliated cranidium USNM 775709. (**2–4**) Exfoliated cranidium USNM 775708: (**2**) dorsal view; (**3**) anterior view; (**4**) oblique view. (**5**) Exfoliated partial pygidium USNM 775712. (**6**) Exfoliated hypostome USNM 775710. (**7**) Inverted photograph of partial pygidium USNM 775711. (**1–4, 6**) Specimens use the 4 mm scale bar; (**5, 7**) specimens use the 2 mm scale bar.

Family Lonchocephalidae Hupé, 1955
Genus *Glaphyraspis* Resser, 1937

Type species.—*Liostracus parvus* Walcott, 1899, upper Cambrian, Wyoming (by original designation).

Glaphyraspis sp. indet.
Figure 18.1

Occurrence.—Nounan Formation (*Cedaria* Biozone), Smithfield Canyon, Utah (see Appendix).

Remarks.—Two small cranidia have a parallel-sided glabella, wide fixigena, and a very thin anterior border similar to a form found by Eby (1981) from the lower *Crepicephalus* Biozone of the House Range, Utah. These specimens may represent a new species, but the lack of material requires open nomenclature.

Family Menomoniidae Walcott, 1916a
Genus *Menomonia* Walcott, 1916a

Type species.—*Conocephalites calymenoides* Whitfield, 1878, Eau Claire Formation, Wisconsin (by original designation).

Menomonia cf. *M. tuberculata* Rasetti, 1965
Figure 18.2

1965 *Menomonia tuberculata* Rasetti, p. 62, p. 2, figs. 19–24.

Holotype.—Cranidium USMN 144696 from the Maryville Limestone, Hawkins County, near Rogersville, Tennessee, USA.

Occurrence.—Nounan Formation (*Cedaria* Biozone), Smithfield Canyon, Utah (see Appendix).

Remarks.—A single librigena with the characteristic surface sculpture and shape of *M. tuberculata* Rasetti, 1965 was found. The Nounan specimen differs in have a larger range in tubercle sizes than the single librigena illustrated by Rasetti (1965, p. 2, fig. 22). This taxon is from the *Cedaria* Biozone of the Maryville Limestone of Tennessee (Rasetti, 1965).

Family Phylacteridae Ludvigsen and Westrop in Ludvigsen, Westrop, and Kindle, 1989
Genus *Cliffia* Wilson, 1951

Type species.—*Acrocephalites latagenae* Wilson, 1949, Morgan Creek Member, Wilberns Formation, Texas (by original designation).

Cliffia sp. indet.
Figure 12.6

Occurrence.—St Charles Formation (*Elvinia* Biozone), Smithfield Canyon, Utah (see Appendix).

Remarks.—A single triangular-shaped pygidium with prominent intrapleural furrows, broad axial furrows with faint nodes, and long axis resembles either *Cliffia* (see Wilson, 1951, pl. 90, fig. 22; Westrop, 1986, pl. 27, figs. 4–6) or *Aphelotoxon* Palmer, 1965 (pl. 19, figs. 6, 11). Given the prominent pleural bands and elongated axis, the specimen is assigned to *Cliffia*; however, the broadness of the axis is more typical of *Aphelotoxon*.

Family Parabolinoididae Lochman, 1956
Genus *Taenicephalus* Ulrich and Resser in Walcott, 1924

Type species.—*Conocephalites shumardi* Hall, 1863 from the Lone Rock Formation, Wisconsin (by original designation).

Taenicephalus westropi Chatterton and Gibb, 2016
Figure 23.1–23.10, 23.12–23.14

1986 *Taenicephalus* sp. A, Westrop, p. 51, pl. 22, figs. 14–16.
2016 *Taenicephalus westropi* Chatterton and Gibb, p. 81, pl. 57, figs. 1–5, 7.

Holotype.—Articulated carapace (UA14129) from the McKay Group, high in Green Creek Section, British Columbia, Canada.

Occurrence.—St. Charles Formation (*Taenicephalus* Biozone), Smithfield Canyon, Utah (see Appendix); Bison Creek

Formation (*Taenicephalus* Biozone), Alberta (Westrop, 1986); McKay Group, British Columbia (Chatterton and Gibb, 2016).

Remarks.—Specimens from the St. Charles Formation are similar to *Taenicephalus* sp. A of Westrop (1986) in their smooth surfaces and subequally divided frontal area. Chatterton and Gibb (2016) assigned Westrop's specimens to *T. westropi* on the basis of complete specimens preserved in shale. The St. Charles specimens are also similar to *T. shumardi* (Hall, 1863) illustrated by Westrop (1986, pl. 21, figs. 5–17) in their convex preglabellar area, anterior border length, position of the palpebral lobes, and nature of the pygidium, but the latter has a more textured surface and an unequal division of the frontal area.

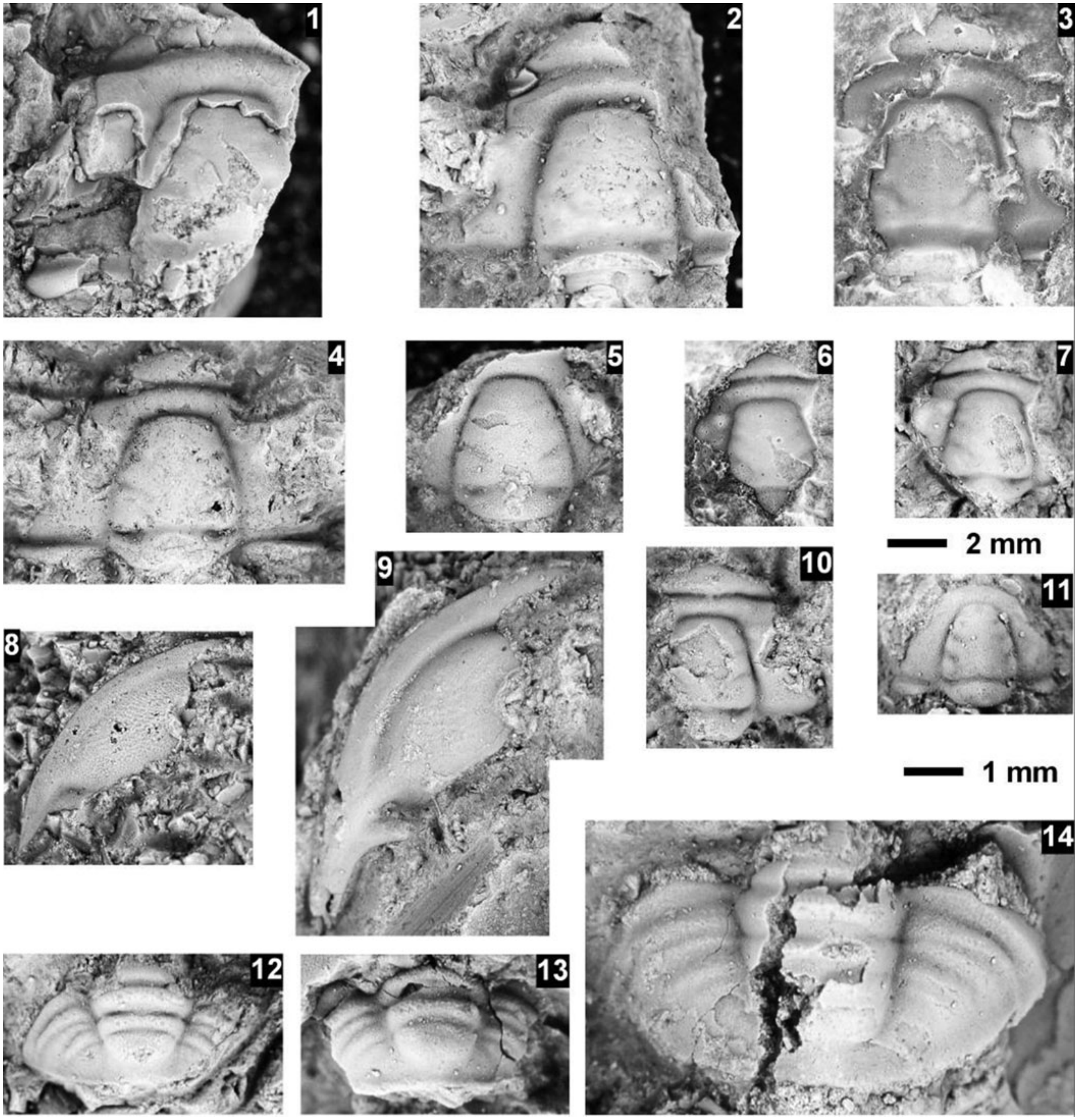

Figure 23. Trilobites from the *Taenicephalus* Biozone, Sunwaptan Stage, St. Charles Formation, Smithfield Canyon, Utah. All specimens are from USNM loc. 44302, in dorsal view. (**1–10, 12–14**) *Taenicephalus westropi* Chatterton and Gibb, 2016: (**1**) mostly exfoliated cranidium USNM 781844; (**2, 3**) part, counterpart of exfoliated cranidium USNM 781848, inverted photograph of internal mold; (**4**) exfoliated cranidium USNM 781847; (**5**) exfoliated cranidium USNM 781845; (**6, 7**) part, counterpart of exfoliated cranidium USNM 781852; (**8**) testate librigena USNM 781850; (**9**) exfoliated librigena USNM 781849; (**10**) mostly exfoliated cranidium USNM 781846; (**12**) exfoliated pygidium USNM 781854; (**13**) exfoliated pygidium USNM 781853; (**14**) exfoliated pygidium USNM 781855. (**11**) *Kendallina* sp. indet. exfoliated cranidium USNM 781851. (**1–10**) Specimens use the 2 mm scale bar; (**11–14**) specimens use the 1 mm scale bar.

Genus *Kendallina* Berg in Moore, 1959

Type species.—*Conocephalites eryon* Hall, 1863, from the Loan Rock Formation, Wisconsin (by original designation).

Kendallina sp. indet.
Figure 23.11

Occurrence.—St. Charles Formation (*Taenicephalus* Biozone), Smithfield Canyon, Utah (see Appendix).

Remarks.—A single small cranidium is here reported from the St. Charles Formation. The specimen is similar to *Kendallina eryon* illustrated by Westrop (1986, pl. 16, figs. 11–13) in cranidial shape but has deeper lateral glabellar furrows. The specimen is also similar to *Kendallina crassitesta* Westrop, 1986 (pl. 20, figs.1–6, pl. 21, figs. 3, 4; Chatterton and Gibb, 2016, pl. 55, figs. 1–10) but differs in the presence of a nonpitted anterior border furrow, more tapered glabella, and deeper glabellar furrows. These features could be the result of ontogeny given the small size of the specimen reported herein; thus, the specimen is left in open nomenclature.

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Declaration of competing interests

The authors declare none.

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Appendix

Localities

Samples are from three measured sections approximately 1.5 miles from the trailhead of Smithfield Canyon, 5 miles east of Smithfield, Utah. Correlations of sections one and two use the base of the ~9 m thick thrombolite horizon as a datum. Correlations of sections two and three use the top of the Worm Creek Member of the St. Charles Formation as a datum. Sample horizons are reported as total meterage from the base of the composite section with meterage from the base of individual sections in parentheses.

Smithfield Canyon—Section 1

Measured by C.M.D. and described by H.R.C. on the southwest-facing slope starting at approximately 7,800 ft elevation and 1,110 ft above the trail. This section is on the ridge between the two north–south drainages north of the "Grotto Ridge." A total of 115 m was measured starting at the first exposure above a vegetated drainage; 0–21 m was measured on 28 June 2021 and 21–115 m was measured on 9 September 2021. Samples collected by C.M.D. and H.R.C. on 28 June 2021.

Bottom of section at 41.90311°, –111.70677°; top at 41.90313°, –111.70665°.

USNM-44289: Thinly bedded to wavy bedded trilobite packstone to grainstone interbedded with siltstone to shale at 11.0 m (11.0 m). *Cedaria* Biozone. *Glaphyraspis* sp. indet., *Coosia*? sp. indet., *Menomonia* cf. *M. tuberculata*, agnostid sp.

USNM-44290: Thinly bedded to wavy bedded trilobite packstone to grainstone interbedded with siltstone to shale at 18.5 m (18.5 m). *Crepicephalus* Biozone. *Kingstonia smithfieldensis* n. sp., *Blountia* sp. indet., *Genevievalla* sp. indet., "*Coosella*" *berryi*, *Coosina* cf. *C. amage, Welleraspis*? sp. indet.

Smithfield Canyon—Section 2

Measured by C.M.D. and described by H.R.C. on the west-facing slope starting at approximately 7,200 ft elevation and 800 ft above the trail. This section is on the ridge east of the second (west to east) drainage north of the "Grotto Ridge." A total of 120 m was measured starting at the top of a dolomite cliff (correlative to ~50–75 m in section 1); 0–33 m was measured 15 November 2021, 33–90 m was measured 2 July 2021, and 90–120 m was measured 7 August 2021.

Bottom of section at 41.90042°, –111.70185°; top at 41.90042°, –111.70185°.

USNM-44291: Sandy, trough cross-bedded, trilobite grainstone at 129.5 m (56 m). *Aphelaspis* Biozone. Collected by C.M.D. and H.R.C. 2 July 2021. *Tumicephalus depressus*, *Aphelaspis* cf. *A. arsoides.*

USNM-44292: Sandy, trough cross-bedded, trilobite grainstone at 130.6 m (57 m). *Aphelaspis* Biozone. Collected by C.M.D. and H.R.C. 2 July 2021. *Tumicephalus depressus*, *Aphelaspis* cf. *A. arsoides.*

USNM-44293: Sandy, trough cross-bedded, trilobite grainstone at 131.2 m. *Aphelaspis* Biozone. Collected by C.M.D. and H.R.C. 2 July 2021. *Tumicephalus depressus*, *Aphelaspis* cf. *A. arsoides.*

USNM-44294: Sandy, trough cross-bedded, trilobite grainstone at 131.7 m (58 m). *Aphelaspis* Biozone. Collected by C.M.D. and H.R.C. 28 June 2021. *Aphelaspis subditus.*

USNM-44295: Sandy, trough cross-bedded, trilobite grainstone at 132.4 m (59 m). *Aphelaspis* Biozone. Collected by C.M.D. and H.R.C. 28 June 2021. *Aphelaspis subditus.*

USNM-44296: Rippled trilobite grainstone with interbedded (5 cm thick) sand stringers at 141 m (67.5 m). *Prehousia* Biozone. Collected by C.M.D. and H.R.C. 8 August 2021.

Bromella utahensis, Dytremacephalus cf. *D. asperaxis, Cheilocephalus* sp. indet.

USNM-44297: Normally graded oolite packstone interbedded with trilobite grainstone at 142 m (68.5 m). *Dunderbergia* Biozone. Collected by C.M.D. and H.R.C. 28 June 2021. *Dytremacephalus* cf. *D. granulosus*.

USNM-44298: Sandy trilobite grainstone at 151.8 m (78 m). *Dunderbergia* Biozone. Collected by C.M.D. and H.R.C. 7 August 2021. *Elburgia*? sp. indet., *Iddingsia* cf. *I. intermedia*, Dokimocephaliid sp. indet.

USNM-44299: Trilobite grainstone interbedded with shale at 183.2 m (110 m). *Elvinia* Biozone. Collected by C.M.D. and H.R.C. 7 August 2021. *Housia ovata, Irvingella* sp., Dokimocephaliid sp. indet.

USNM-44300: Trilobite grainstone at 189.5 m (116 m). *Elvinia* Biozone. Collected by C.M.D. and H.R.C. 7 August 2021. *Pseudosaratogia* sp. indet.

USNM-44301: Trilobite grainstone with intraclastic conglomerate at 190.5 m (117 m). *Elvinia* Biozone. Collected by C.M.D. and H.R.C. 7 August 2021. *Cliffia* sp. indet., *Elvinia* sp. indet., *Irvingella* cf. *I. flohri*, *Iddingsia* sp. indet., *Pseudosaratogia* sp. indet., *Pseudagnostus josepha*?.

Smithfield Canyon—Section 3

Measured by C.M.D. and described by H.R.C. on the “Grotto Ridge” starting at 7,000 ft elevation and 400 ft above the trail. A total of 180 m was measured on 17 June 2022 beginning at the top the Worm Creek Member of the St. Charles Formation. Samples collected by C.M.D. and H.R.C. 17 June 2022.

Bottom of section at 41.89525°, –111.70109°; top at 41.89247°, –111.69478°.

USNM-44302: Medium-bedded trilobite grainstone with sandy stringers at 183.2 m (25.7 m). *Taenicephalus* Biozone. *Noelaspis*? sp. indet., *Taenicephalus westropi*, *Kendallina* sp. indet., *Pseudagnostus josepha*.

USNM-44303: Thinly bedded to wavy-bedded trilobite grainstone at 189.5 m (34.5 m). *Ellipsocephaloides* Biozone. *Wilbernia* aff. *W. pero*, *Wilbernia* aff. *W. expansa*, *Pseudagnostus josepha.*

USNM-44304: Trilobite packstone with trilobite lags at 190.5 m (55 m). *Ellipsocephaloides* Biozone. *Saratogia* (*Idahoia*) aff. *S.* (*I.*) *fria*, *Wilbernia* cf. *W. explanata*, *Pseudagnostus josepha*.

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