

Middle Cambrian trilobites (Miaolingian, *Ehmaniella* Biozone) from the Telt Bugt Formation of Daugaard-Jensen Land, western North Greenland

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A small fauna of middle Cambrian trilobites is described from the upper Telt Bugt Formation of Daugaard-Jensen Land, western North Greenland, and the formation is formally defined. *Blainiopsis holtedahli* and *Blainiopsis benthami*, originally described from the equivalent Cape Wood Formation of Bache Peninsula, Nunavut, Canada, are documented in an assemblage assigned to the *Ehmaniella* Biozone (Topazan Stage of North American usage), Miaolingian Series, Wuliuan Stage, of the international standard. Two new species are proposed: *Ehmaniella sermersuaqensis* and *Clappaspis tupeq*.

Keywords: Laurentia, North Greenland, Cambrian, Miaolingian (Wuliuan), trilobites.

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The first Cambrian fossils from the Nares Strait region, the narrow waterway separating northernmost Greenland and Canada, were collected from Bache Peninsula (Fig. 1A, locality 3) by Norwegian geologist Per Schei (1875–1905) as a participant in the Second Norwegian Arctic Expedition in the ‘Fram’ (1898–1902). Schei’s poorly preserved ptychoparioid trilobites from Nunavut were described by Holtedahl (1913). Poulsen (1946) incorporated them into his account of the larger collections from the same locality made by Robert Bentham as a member of the Oxford University Ellesmere Land Expedition (1934–1935).

In Greenland, dog sledge expeditions between 1916 and 1923 by the Danish cartographer and geologist Lauge Koch (1892–1964) produced extensive fossil collections that established the Greenland coast from Kane Basin northwards (Fig. 1A) as a classic area of Lower Palaeozoic palaeontology in the Canadian Arctic Archipelago (Poulsen 1927, 1934, 1941, 1943; Troedsson 1926, 1928). Cambrian stratigraphy and faunas were described from Inglefield Land in Greenland by Christian Poulsen (1927) who introduced a large number of new trilobites, many of which were recognised subsequently by paleontologists working elsewhere in Laurentia (Resser 1935, 1938, 1939a; Ra-

setti 1951; Cooper *et al.* 1952; Palmer & Halley 1979). Several of the lithostratigraphic and biostratigraphic problems recognised in Poulsen’s (1927) studies were later addressed by Johannes C. Troelsen (1913–1992) during the Danish Thule–Ellesmere Island Expedition (1939–1941). Troelsen visited both Ellesmere Island and the coast of Inglefield Land (Troelsen 1950), and specimens he collected were described by Christian Poulsen (1958), his son Valdemar Poulsen (1964) and Peel (2020).

Due to poor ice conditions, the dog sledges which carried the expeditions of Koch and Troelsen journeyed offshore in front of Humboldt Gletscher from northern Inglefield Land to Kap Clay and Cass Fjord (Fig. 1A,C). Thus, Cambrian fossils were not discovered in Daugaard-Jensen Land on the northern margin of Humboldt Gletscher until geologists of the Greenarctic Consortium collected late Cambrian (Furongian) trilobites from the Cass Fjord Formation during hydrocarbon prospecting in 1969 (Dawes 1976; Palmer & Peel 1981). The collections described herein, and those described by Palmer & Peel (1981), were assembled in the course of field work by Grønlands Geologiske Undersøgelse during 1975–1977 (Henriksen & Peel 1976; Palmer & Peel 1981). Regional geological

surveying adjacent to Humboldt Gletscher was resumed by Grønlands Geologiske Undersøgelse (now Geological Survey of Denmark and Greenland, GEUS) in 1999 (Dawes 2004; Dawes *et al.* 2000), but additional collections of Cambrian fossils were not made.

The present paper describes middle Cambrian (Miaolingian Series, Wuliuan Stage; *Ehmaniella* Biozone) trilobites from the Telt Bugt Formation of Daugaard-Jensen Land, on the north side of Humboldt Gletscher. The name Telt Bugt Formation was intro-

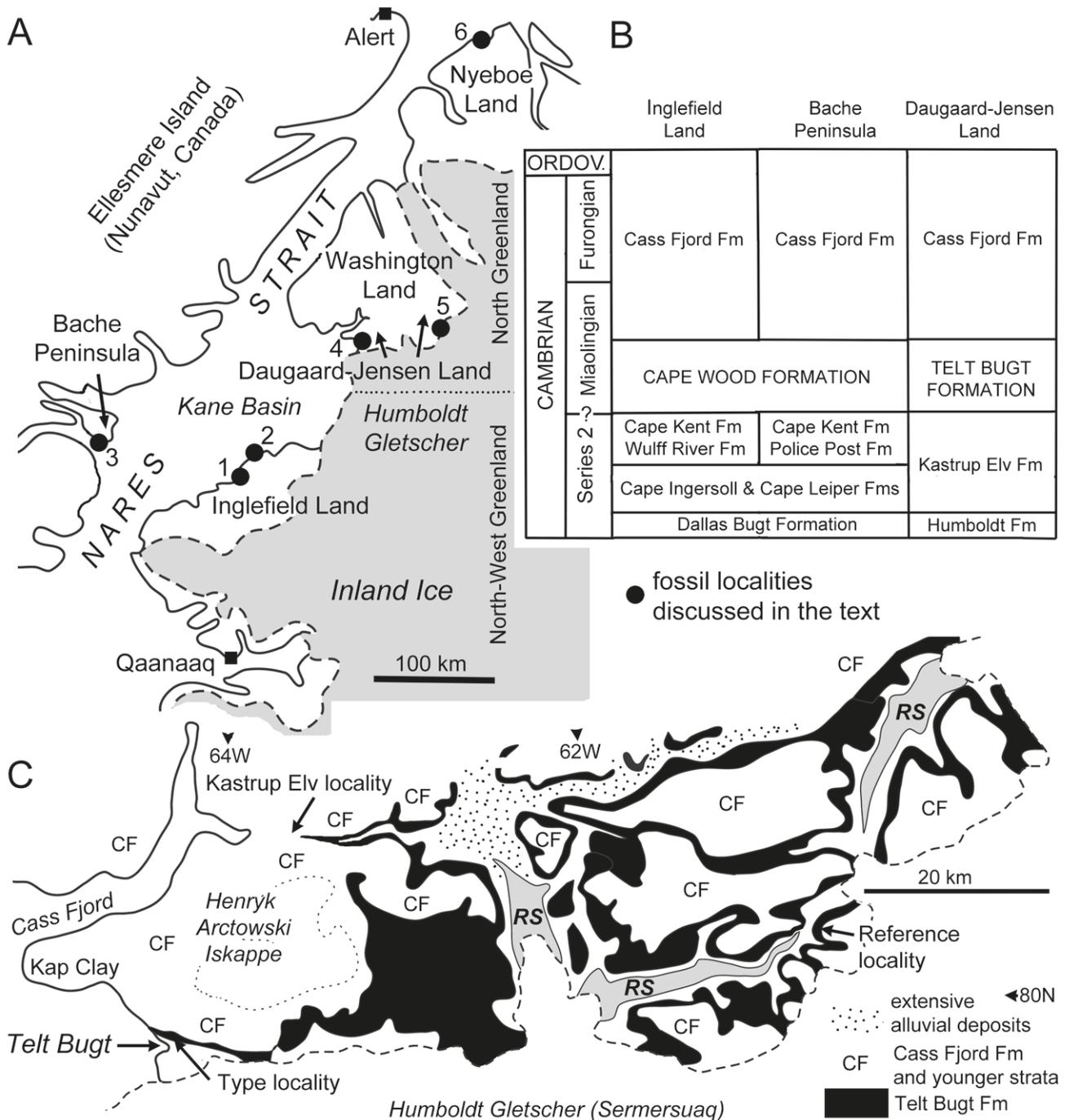


Fig. 1. A: The area around Nares Strait showing localities for Miaolingian fossil assemblages. 1, Kap Russell and Marshall Bugt, Inglefield Land. 2, Blomsterbækken, Kap Frederik VII, Kap Wood and Kap Kent, Inglefield Land. 3, Bache Peninsula, Ellesmere Island, Nunavut; 4, Telt Bugt, Daugaard-Jensen Land; 5, Romer Søer, Daugaard-Jensen Land; 6, Hand Bugt, Nyeboe Land. **B:** Cambrian stratigraphy around Kane Basin (after Peel 2020). **C:** Outcrops of the Telt Bugt Formation in Daugaard-Jensen Land showing location of type section (Fig. 1A, locality 4) and reference locality (Fig. 1A, locality 5) at Romer Søer (RS).

duced by Henriksen & Peel (1976) for a stratigraphic unit in Daugaard-Jensen Land which was found to be equivalent to the Cape Wood Formation of Inglefield Land and Bache Peninsula (Fig. 1B; Poulsen 1927, 1964; Troelsen 1950; Peel & Christie 1982; Dawes 2004). The Telt Bugt Formation is now formally described. Together with the trilobites *Glossopleura* Poulsen 1927 and *Polypleuraspis* Poulsen 1927 recently described by Peel (2020) from slightly older Wuliuian Stage (*Glossopleura walcotti* Biozone) strata of the Cape Wood Formation and the lower Telt Bugt Formation, the new descriptions consolidate understanding of the Cambrian record in Greenland straddling Humboldt Gletscher. However, the faunal transition from the middle to late Cambrian (Miaolingian Series–Furongian Series) in the restricted shelf environments of Inglefield Land and Daugaard-Jensen Land remains incomplete in the absence of records of the Drumian Stage (medial Miaolingian Series), although strata of this age are known from outer shelf successions in Nyeboe Land, to the north (Peel 1994).

Geological background

An overview of the geology of the Humboldt Gletscher area of Greenland, including a 1:500 000 geological map, was given by Dawes (2004).

The Telt Bugt Formation is one of many formations comprising the Ryder Gletscher Group (Higgins *et al.* 1991; Watt 2019). The Ryder Gletscher Group was formally defined by Ineson & Peel (1997) and ranges stratigraphically from the early Cambrian (Cambrian Stage 4) to the Middle Ordovician. Its carbonate dominated sediments crop out from the Nares Strait area eastward across North Greenland and represent an aggradational sequence that accumulated in Greenland on the craton side of the trans-arctic Franklinian Basin succession.

Telt Bugt Formation

History. The name was introduced by Henriksen & Peel (1976) in Daugaard-Jensen Land (Fig. 1) and discussed subsequently by Palmer & Peel (1981), Peel & Christie (1982), Dawes (2004), Peel (2020) and Watt (2019); see also Dewing *et al.* (2001).

Type locality. Telt Bugt, south-west Daugaard-Jensen Land, western North Greenland (Fig. 1C). The log of the type section (Fig. 2) was compiled by N. Henriksen and J.S. Peel on 7th–8th July 1975 from a succession of low bluffs on the northern side of the bay, 1–2 km inland (79°56' N, 64°12' W). Base of section about 75 m a.s.l.

Lithology. The formation is dominated by thinly bedded, fossiliferous, grey, lime mudstone with silty laminae and intercalations that become more abundant in the upper part of the formation in its type section. Individual beds are only a few centimetres thick and often laterally discontinuous. Dolomite infilled burrows are abundant, often giving rise to a characteristic scoriaceous weathering surface with the burrows in positive relief.

Boundaries. The Telt Bugt Formation overlies the Kastrup Elv Formation with a gradational boundary in the type section, with 10–50 cm thick bands of dolomite and limestone alternating through about 10 m; limestone beds increase in frequency upwards. In some localities to the east, the boundary is marked by a dolomitisation front rising from the underlying

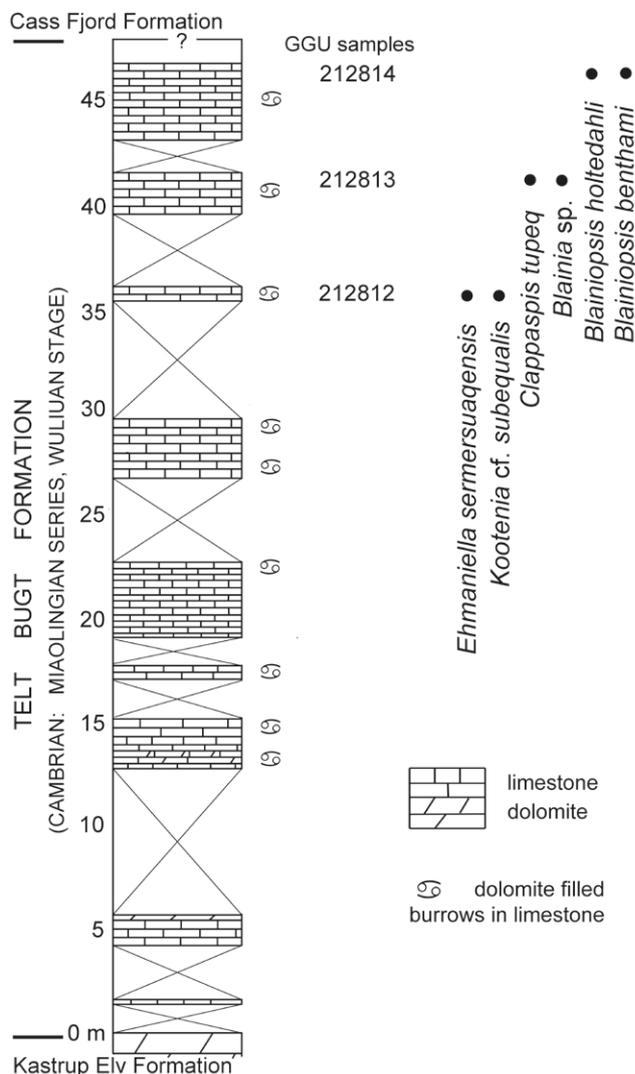


Fig. 2. Distribution of trilobites in the upper Telt Bugt Formation at the type locality at Telt Bugt, Daugaard-Jensen Land (Fig. 1C).

Kastrup Elv Formation. The boundary with the overlying Cass Fjord Formation is gradational, and in the type section it is placed at the first appearance of the intraformational conglomerate beds (about 30 cm and thicker) that are characteristic of the overlying Cass Fjord Formation.

Thickness. The formation attains a thickness of about 45 m in the type section, increasing to approximately 100 m at Romer Søer (Fig. 1C), but thins rapidly to the north. At Kastrup Elv (Fig. 1C) the formation is reduced in thickness to only about 5 m and is often hidden under talus from the overlying Cass Fjord Formation.

Distribution. Daugaard-Jensen Land (Fig. 1C). The Telt Bugt Formation is equivalent to the Cape Wood Formation of Inglefield Land and Bache Peninsula (Christie 1967; Peel & Christie 1982; Fig. 1B).

Age. Trilobites indicate a middle Cambrian age (Miaolingian Series), ranging throughout much of the Wuliuan Stage (Delamaran and Topazan stages of North American usage). *Glossopleura* and *Polypleuraspis* (Wuliuan Stage, *Glossopleura walcotti* Biozone) were described from the lower half of the formation at a reference locality in the Romer Søer area by Peel (2020; Fig. 1C, see also locality 5 in Fig. 1A). Faunas described herein from the upper part of the formation at Telt Bugt (Fig. 2) are assigned to the *Ehmaniella* Biozone. Fossils indicative of the Drumian Stage are not known. The overlying Cass Fjord Formation ranges in age from the late Miaolingian Series, Guzhangian Stage, into the Early Ordovician (Palmer & Peel 1981).

Material. GGU samples 212812–212814 were collected by J.S. Peel on 8th July 1975 from the type locality of the Telt Bugt Formation (Figs 1A, locality 4; 1C; 2), east of Telt Bugt, Daugaard-Jensen Land.

Biostratigraphy and correlation

In summarising the Miaolingian record of Inglefield Land, V. Poulsen (1964) assigned trilobite faunas to three of the five genus-based biostratigraphic biozones widely recognised in the Pacific coast region of Laurentia (see Babcock *et al.* 2011 for a historic summary). The oldest of these, the *Plagiura–Poliella* Biozone, was recognised only on the basis of rare fossils contained within clasts from the basal conglomerate of the Cape Wood Formation at Blomsterbækken (Fig. 1A, locality 2). The succeeding *Albertella* Biozone was not recognised in Inglefield Land, with most of the Cape Wood Formation yielding a *Glossopleura* Biozone fauna. The upper part of the formation was assigned

to the *Bathyuriscus–Elrathina* Biozone but no faunas defining the overlying *Bolaspidella* Biozone (Drumian Stage) were identified.

In more recent terminology, the genus-based zonal scheme used by V. Poulsen (1964) has been replaced in part by nomenclature proposed by Sundberg (2005, 2018) and McCollum & Sundberg (2007). Thus, the *Glossopleura* Biozone is now known as the *Glossopleura walcotti* Biozone (McCollum & Sundberg 2007) or the *Glossopleura walcotti/Ptychagnostus praecurrens* Biozone (Sundberg 2018), and trilobites of this age were described from the Telt Bugt Formation in eastern Daugaard-Jensen Land by Peel (2020). The *Bathyuriscus–Elrathina* Biozone faunas of V. Poulsen (1964) lie within the *Ehmaniella* Biozone of Sundberg (1994) and McCollum & Sundberg (2007), and trilobites described in the present paper are derived from this biozone (Figs 2–5).

Elsewhere in Greenland, the *Glossopleura walcotti* Biozone was documented in the Henson Gletscher Formation of northern Nyeboe Land (Fig. 1A, locality 6) by Babcock (1994). It is not reported from outer shelf successions in more eastern areas of North Greenland where the lower Miaolingian *Oryctocephalus indicus* Biozone is followed by the late Wuliuan *Ptychagnostus gibbus* Biozone (Geyer & Peel 2011).

In eastern Nunavut, the *Glossopleura walcotti* Biozone was documented within the Parrish Glacier Formation (absorbed into the Cass Fjord Formation by Dewing *et al.* 2001) by de Freitas (1998a,b), as well as on Bache Peninsula (Poulsen 1946; Christie 1967; Peel 2020). The occurrence of *Glossopleura* and *Polypleuraspis* in the Bear Point Formation of Devon Island, Nunavut, to the south-west, was noted by Peel (2011).

The *Ehmaniella* Biozone fauna of the Telt Bugt Formation (Figs 3–5) shares *Blainiopsis* Poulsen 1946 and *Blainia* Walcott 1916 (as *Glyphaspis* Poulsen 1927) with that of the Cape Wood Formation in Inglefield Land. While *Blainia* is widely distributed in Laurentia (Bordonaro *et al.* 2013), *Blainiopsis* is only certainly known from the Kane Basin area. In Argentina, *Blainia gregaria* Walcott 1916 was reported from the *Bolaspidella* Biozone of the La Laja Formation by Bordonaro *et al.* (2013) but some of the synonymised species occur also in the *Ehmaniella* Biozone. Individual fossil samples from the upper Telt Bugt Formation have low diversity. Due to the lack of accompanying taxa, it is assumed by comparison with Inglefield Land (V. Poulsen 1964) that *Blainiopsis* in GGU sample 212814 (Fig. 2) indicates the *Ehmaniella* Biozone. Thus, there is no firm evidence for the presence of the *Bolaspidella* Biozone (Drumian Stage) in the restricted inner shelf succession around the Kane Basin, although the presence of a *Ptychagnostus atavus* fauna in the Henson Gletscher Formation of northern Nyeboe Land (Fig. 1A, locality 6) described

by Robison (1994) confirms the Drumian Stage in outer shelf successions. *Ptychagnostus atavus* Biozone strata were also reported but not described in eastern Ellesmere Island by de Freitas (1998b). Drumian strata occur in outer shelf deposits in the Freuchen Land–Peary Land region of eastern North Greenland, as discussed by Geyer & Peel (2017). The oldest Cambrian faunas known from the overlying Cass Fjord Formation in Daugaard-Jensen Land were recorded by Palmer & Peel (1981), some 50 m stratigraphically higher than the highest sampled fossiliferous horizon (GGU sample 212814) in the Telt Bugt Formation (Fig. 2), and indicate the *Cedaria* Biozone (Guzhangian Stage).

logical type collection of the Museum of Evolution, Uppsala University, Uppsala, Sweden. GGU prefix indicates a sample taken during regional geological campaigns of Grønlands Geologiske Undersøgelse (Geological Survey of Greenland), Copenhagen, Denmark. In the following descriptions, sagittal and transverse are abbreviated to (sag.) and (trans.), denoting dimensions measured parallel or transverse to the axis, respectively.

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Systematic palaeontology

Repositories and abbreviations. Type and figured specimens (PMU prefix) are deposited in the palaeonto-

Class Trilobita Walch 1771

Order Corynexochida Kobayashi 1935

Family Dorypygidae Kobayashi 1935

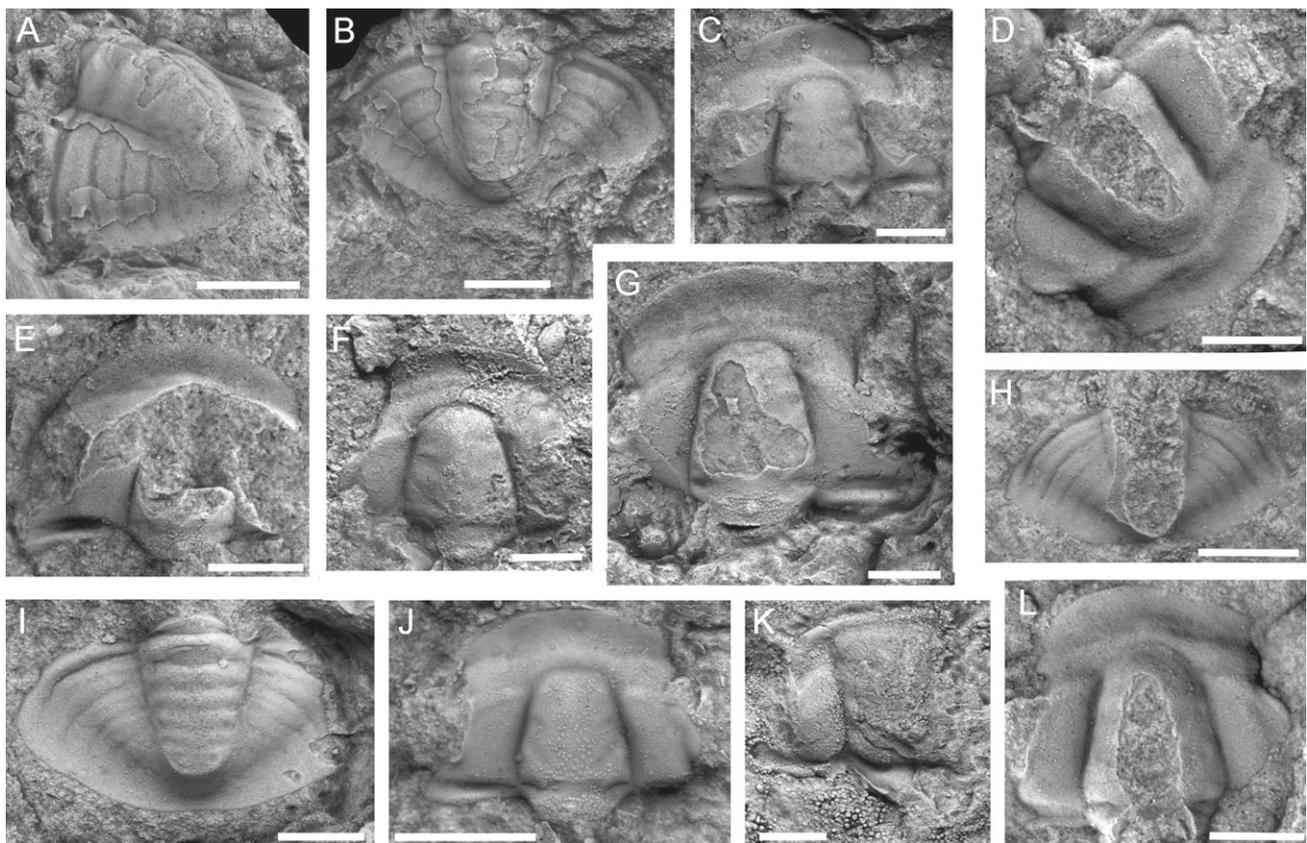


Fig. 3. *Ehmaniella* and *Kootenia* from the Telt Bugt Formation (Miaolingian) of Daugaard-Jensen Land. All specimens from GGU sample 212812. Specimens coated with black colloidal carbon and then whitened with ammonium chloride sublimate prior to photography. Scale bars are 2 mm. **A–J,L:** *Ehmaniella sermersuaqensis* sp. nov. **A,B:** PMU 35693, partly exfoliated pygidium in oblique lateral (A) and dorsal (B) views. **C:** PMU 35694, cranium with damaged palpebral areas. **D,L:** PMU 35695, cranium with damaged glabella in antero-dorsal (D) and dorsal (L) views. **E:** PMU 35696, damaged cranium. **F:** PMU 35697, cranium. **G:** PMU 35698, cranium. **H:** PMU 35699, pygidium with damaged axis. **I:** PMU 35700, pygidium. **J:** PMU 35701, holotype, cranium. **K:** *Kootenia* cf. *subequalis* Deiss 1939. PMU 35702 damaged cranium.

Genus *Kootenia* Walcott 1889

Type species. *Bathyriscus (Kootenia) dawsoni* Walcott 1889 from the Stephen Formation (Miaolingian) of British Columbia.

Kootenia cf. *subequalis* Deiss 1939

Fig. 3K

Figured material. Cranidium, PMU 35702 from GGU sample 212812, Telt Bugt Formation, Telt Bugt, Daugaard-Jensen Land.

Discussion. The straight sides and perpendicular transition to the shallowly convex front of the glabella of this fragmentary glabella are similar to the unique specimen of *Kootenia subequalis* Deiss 1939 from the Pentagon Shale (Miaolingian) of Montana, but the posterior fixed cheeks are shorter in the Greenland specimen. Both specimens are poorly preserved.

Order Ptychopariida Swinnerton 1915

Suborder Ptychopariina Richter 1933

Family Alokistocaridae Resser 1939b

Genus *Ehmaniella* Resser 1937

Type species. *Crepicephalus (Loganellus) quadrans* Hall & Whitfield 1877 from the Spence Shale (Miaolingian) of Utah, U.S.A.

Ehmaniella sermersuaqensis sp. nov.

Fig. 3A–J, L

Holotype. PMU 35701 from GGU sample 212812, Telt Bugt Formation, Telt Bugt, Daugaard-Jensen Land.

Figured material. Cranidia: PMU 35694–PMU 35698. Pygidia: PMU 35699–PMU 35701. All from GGU sample 212812, Telt Bugt Formation, Telt Bugt, Daugaard-Jensen Land.

Derivation of name: From Sermersuaq, the Greenlandic name for Humboldt Gletscher (Fig. 1).

Diagnosis. Species of *Ehmaniella* in which the short (sag.), convex preglabellar field passes without a sharply defined border furrow onto the broad (sag.), concave border. Pygidium transversely elliptical with five rings and a well-developed concave border partially traversed by interpleural furrows.

Description. The cranidium is trapezoidal with length (sag.) varying from 70% of width in small specimens (Fig. 3J, length 3.2 mm) to 90% in the largest specimen (length about 9 mm). In the same specimens the glabellar length including occipital ring is almost 75% of the cranial length. The glabella is conical with straight to slightly convex sides and a shallowly convex to flattened anterior termination; it is uniformly convex in transverse profile and raised above the shallowly convex fixed cheeks. Three pairs of glabellar furrows are weakly developed or obscure, with the most prominent pair (S1) strongly oblique (Fig. 3J, the smallest figured specimen). The occipital furrow (SO) is broad and shallow medially, but with deep and elongate pits adjacent to the axial furrow. The occipital ring is trapezoidal, laterally short (sag.) but increasing in length medially to about the same dimension as the preglabellar field. A small median node is present in most specimens (Fig. 3G). The axial border furrow is deep and narrow along the sides of the glabella. In most specimens it is broken by the eye ridges joining the glabella (Fig. 3G), becoming wider and more shallow anterior of the eye ridges.

The anterior area consists of a convex preglabellar field passing into a concave border, the latter about twice the width of the preglabellar field. A distinct border between these two elements is absent or only weakly developed immediately in front of the glabella, but shallow border furrows develop laterally as the preocular fields steepen and the anterior limbs of the facial sutures are approached. In some specimens a sliver-like, laterally extended, low swelling is developed in front of the glabella immediately anterior to the obscure border furrow (Fig. 3E). The preglabellar field varies from uniformly convex to subangular, with a rapid transition from the upper surface to the steepened admarginal surfaces (Fig. 3D), which become steeper laterally as they approach the facial sutures. The admarginal surface becomes concave distally as it passes onto the anterior border, which is inclined or slightly upturned. The anterior border has a uniformly convex anterior margin in dorsal view, its axial width (sag.) two to three times the width (sag.) adjacent to the facial sutures (Fig. 3G). Preocular areas vary from slightly narrower (trans.) than the anterior glabella to slightly wider, decreasing somewhat in width as the sutures curve in towards the eye ridges. At the mid-point of the palpebral lobes, the fixed cheeks are about 60% of the corresponding glabellar width (trans.), about 85% of the glabellar width at the posterior border where the border furrows are deep, widening distally.

Broad but poorly defined eye ridges pass obliquely into more sharply defined palpebral lobes and palpebral furrows lying parallel to the sides of the glabella.

These are somewhat more than half the length (sag.) of the glabella, exclusive of the occipital furrow and ring, and are located at its mid-length.

Free cheeks, hyperstome and thorax are not known.

The pygidium is transversely elliptical, with length about half of width (Fig. 3B,I). The lateral angulations, defining the point of maximum width (trans.), lie at half of the length (sag.) and at this point the broad axis has narrowed in width to only half the width of each pleural area including the border. The axis is strongly convex between narrow and deep axial border furrows which become obscure at the posterior tail piece, the latter approaching the posterior border. Six axial rings are present anterior to the tail piece, becoming less clearly defined posteriorly. The pleural areas are initially shallowly convex, becoming increasingly convex before passage into the concave border; a border furrow is not present. Interpleural furrows are more strongly incised than pleural furrows and extend well into the border area (Fig. 3H,I). Pleural segments between consecutive interpleural furrows are flattened.

Ornamentation of fine granules is variably distributed over the glabella and fixed cheeks but becomes coarser and more prominent on the occipital ring and just anterior of the smooth occipital furrow (SO). Fine radiating lines may be developed on the anterior border of the largest specimens.

Discussion. The holotype (Fig. 3J) is the smallest of the illustrated cranidia. Cranidia of *Ehmaniella sermersuaqensis* are abundant, pygidia much less frequent, in the almost monospecific assemblage of GGU sample 212812 (Fig. 3). The cranidium is similar to *Ehmaniella fronsplanata concava* Sundberg 1994, described from the *Ehmaniella* Biozone of Utah and Nevada, in terms of its concave border without a well-defined border furrow. Such a furrow is well developed in other species and subspecies illustrated by Sundberg (1994) where the preglabellar field is also more clearly defined. *Ehmaniella sermersuaqensis* is most readily differentiated from other species of *Ehmaniella* by the form of its pygidium, with a well-developed concave border area. The pygidium of *Ehmaniella fronsplanata fronsplanata* Sundberg 1994, and several specimens from Montana illustrated by Deiss (1939) as *Clappaspis* Deiss 1939, have a similar lenticular shape but only a narrow border.

The cranidium of *Elrathiella obscura* Poulsen 1927, the type species of *Elrathiella* Poulsen 1927, differs from *Ehmaniella sermersuaqensis* in having a strongly developed anterior border furrow and narrow fixed cheeks. These characters are well seen in a cranidium from the Cape Wood Formation of Bache Peninsula

(*Elrathiella* ? sp. of Poulsen 1946) that V. Poulsen (1964) placed in synonymy with *Elrathiella obscura*, but he neither figured nor redescribed the species; its pygidium is not known. The several species from the *Ehmaniella* Biozone of Utah and Nevada assigned to *Elrathiella* by Sundberg (1994) lack the well-developed concave border and lenticular pygidium of *Ehmaniella sermersuaqensis*.

Cranidia from the early Miaolingian part of the Pioche Shale of Nevada assigned to *Achlysopsis* Fritz 1968 by Sundberg (2018) lack the strongly steepened preocular fields of *Ehmaniella sermersuaqensis* and have a more clearly defined anterior border furrow. Their pygidia also have fewer axial rings, and lack the concave border and flattened pleural segments of the Telt Bugt species.

Genus *Clappaspis* Deiss 1939

Type species. *Clappaspis typica* Deiss 1939 from the Pentagon Shale (Miaolingian) of Montana, U.S.A.

Discussion. Deiss (1939) described ten species of his new genus *Clappaspis* from the Miaolingian of Montana. He considered the genus to be most closely related to *Elrathiella* but Resser (1939a) noted its apparent relationship to *Ehmaniella* in describing an additional five new species from the Spence Shale. Resser (1939a) commented that the only differences of consequence were the slightly narrower preglabellar area and the granulated surface of *Clappaspis*. However, *Clappaspis* was regarded as a junior synonym of *Ehmaniella* by Rasetti (1951, p. 100, 220) and by Harrington *et al.* (1959). It is maintained as a separate genus in the present context since the extreme shortness (sag.) of the preglabellar field, transversely straight anterior border furrow and relatively coarse granular ornamentation are in better accord with the Telt Bugt specimens than other published species assigned to *Ehmaniella* (Palmer 1954; Sundberg 1994).

Classaspis tupeq sp. nov.

Fig. 4A–J, M

Holotype. PMU 35706 from GGU sample 212813, Telt Bugt Formation, Telt Bugt, Daugaard-Jensen Land.

Figured material. Cranidia: PMU 35705, PMU 35707. Free cheek: PMU 35708. Pygidia: PMU 35703, PMU 35704, PMU 35709. All from GGU sample 212813, Telt Bugt Formation, Telt Bugt, Daugaard-Jensen Land.

Derivation of name. From *tupeq* (Greenlandic) meaning tent (Danish, *telt*), reflecting the occurrence in the Telt Bugt Formation.

Diagnosis. Species of *Clappaspis* Deiss 1939 with an occluded preglabellar field. Glabellar furrows obscure or lacking.

Description. The cranidium is trapezoidal, with maximum length (sag.) about 80% of width. The conical glabella has straight sides and narrows in width to about 60% from the occipital furrow to the anterior margin; its anterior is uniformly convex. The anterior

field is dominated by a shallowly convex anterior border that tapers laterally and is swollen in front of the glabella (Fig. 4M), with the preglabellar field occluded in front of the glabella (Fig. 4J). The anterior margin is uniformly convex (Fig. 4G) to slightly arched (Fig. 4E) with the anterior border furrow straight (trans.) and deeply incised, though somewhat shallower in front of the glabella (Fig. 4F). Anteriorly, the facial suture is convex, becoming parallel to the axis just prior to

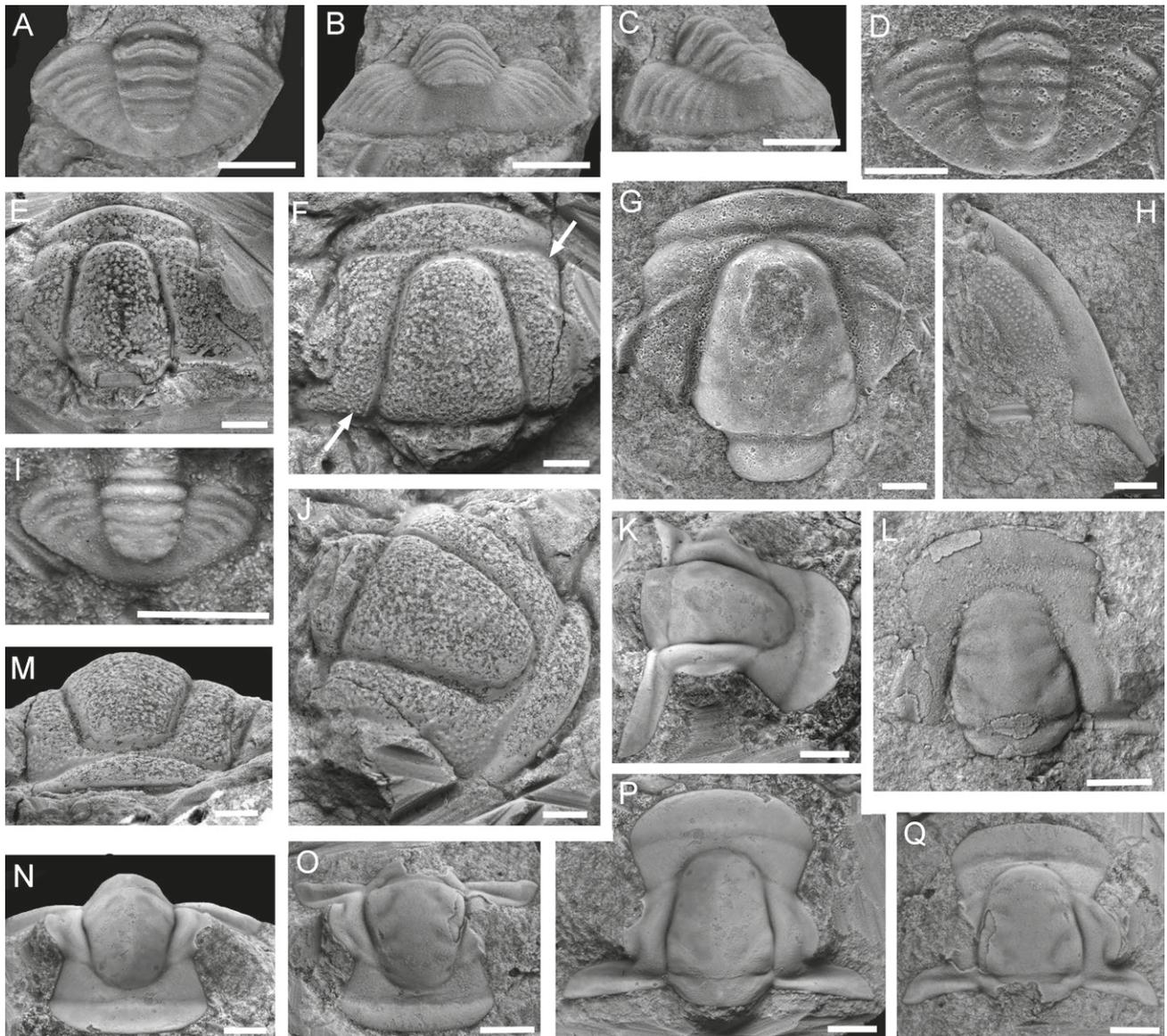


Fig. 4. *Clappaspis* and *Blainia* from the Telt Bugt Formation (Miaolingian) of Dagaard-Jensen Land. All specimens from GGU sample 212813. Specimens coated with black colloidal carbon and then whitened with ammonium chloride sublimate prior to photography. Scale bars are 2 mm. **A–J,M:** *Clappaspis tupeq* sp.nov. **A–C:** PMU 35703, pygidium in dorsal (A), posterior (B) and postero-lateral (C) views. **D,** PMU 35704, pygidium. **E,** PMU 35705, cranidium. **F,J,M:** PMU 35706, holotype, cranidium in dorsal (F), antero-lateral (J) and anterior (M) views; arrows in F indicate patches of granule ornamentation. **G:** PMU 35707, cranidium, digital cast of external mould. **H:** PMU 35708, free cheek. **I:** PMU 35709, pygidium. **K,L,N–Q:** *Blainia* sp. **K,N,P:** PMU 35710, cranidium in oblique lateral (K), anterior (N) and dorsal (P) views. **L,** PMU 35711, partially flattened cranidium. **O,Q:** PMU 35712, cranidium in anterior (O) and dorsal (Q) views.

meeting the oblique eye ridges (Fig. 4E). Palpebral lobes are slightly more than one quarter of the overall glabellar length and are located at the mid-point of the glabella, exclusive of the occipital ring. Each preocular area is almost as wide (trans.) as the anterior of glabella, about half the maximum width (trans.) of each posterior fixed cheek (Fig. 4E).

The axial furrow around the glabella is deep and narrow, joining or almost joining with the anterior border furrow in front of the glabella. The occipital furrow (SO) is straight, deep and narrow, but other glabellar furrows are obscure (Fig. 4F,G). The occipital ring (LO) is long (sag.) but narrows laterally to the posterior border; it is seemingly without a median spine or node.

Free cheeks have a broad, shallowly convex, smooth border with the lateral border furrow becoming shallow or terminating as it approaches the slender genal spine (Fig. 4H).

The thorax, hyperstome and rostral plate are not known. The width (trans.) of the lenticular pygidium (Fig. 4A,D) is almost twice its length (sag.). The axis is broad, almost the same width as the pleural fields exclusive of the narrow border (Fig. 4A,B). There are four axial rings and a tailpiece with an incipient fifth ring. The tailpiece terminates bluntly high above and well short of the posterior margin (Fig. 4A–C). Pleural areas and the axis are heavily furrowed except immediately posterior of axis (Fig. 4C).

Ornamentation consist of tubercles that are most strongly developed on the preocular areas (Fig. 4F, arrows) and free cheeks (Fig. 4F,H).

Discussion. *Clappaspis hebetis* Deiss 1939 from the Pentagon Shale at Lick Creek, Montana, has a laterally less tapering front border than *Clappaspis tupeq* and shorter palpebral lobes. However, the preglabellar field is of similar length (sag.) and the anterior border furrow is similarly straight. Glabellar furrows are weak to moderately developed in *Clappaspis* species from Montana, but generally not visible in Greenland specimens. Ornamentation of *Clappaspis* from Montana consists of scattered coarse tubercles dispersed against a background of finer granules. The cranium in available specimens of *Clappaspis tupeq* is usually covered by granules of uniform size (arrows in Fig. 4F) but weathering often produces a pitted character (Fig. 4E,F). The free cheek is also granulate, but the border is smooth (Fig. 4H).

Modocia planata Robison 1988 from the Holm Dal Formation (Miaolingian, Guzhangian Stage) of eastern North Greenland resembles *Clappaspis tupeq* in terms of its straight anterior border furrow and the narrowness of the preglabellar field. The border, however, is shorter and the glabella is narrower and more rounded

anteriorly than in *Clappaspis tupeq*. The pygidium of *Clappaspis tupeq* is more lenticular than that of *M. planata* and its margin is not arched beneath the axis. One more ring is present in the pygidial axis of *Clappaspis tupeq* than in *M. planata* and this terminates at a greater distance from the margin.

Ithyektyphus tetonensis (Miller 1936) from the late Middle Cambrian of Wyoming, as described by Lochman & Hu (1960), differs in having a glabella with slightly convex sides and marginally longer (sag.) preglabellar field. Its pygidium resembles a small pygidium from the Telt Bugt Formation (Fig. 4I) but was reported to carry small marginal spines not present in *Clappaspis tupeq*. Larger pygidia of the latter species (Fig. 4A–D) have sharper lateral angles and wider axial furrows. Additionally, the first and second axial rings show a narrow transverse median furrow (Fig. 4A,D).

Robison (1964, pl. 89, figs 20–22) illustrated an undetermined cranium from the Wheeler Shale of Utah which closely resembles *Clappaspis tupeq* but has a narrower glabella, an upturned brim with deep anterior border furrow and coarse tuberculate ornamentation.

Ptychoparella brevicauda Poulsen 1927, revised by V. Poulsen (1964), from the lower Cape Wood Formation of Inglefield Land, differs from *Clappaspis tupeq* in its longer (sag.) preglabellar area, wider fixed cheeks and weakly curved anterior border.

Family Asaphiscidae Raymond 1924

Genus *Blainia* Walcott 1916

Type species. *Asaphiscus (Blainia) gregarius* Walcott 1916 from the Conasauga Formation (Miaolingian) of Alabama, U.S.A.

Discussion. *Blainia* was described by Walcott (1916) from the Conasauga Formation of Alabama as a subgenus of *Asaphiscus* Meek 1873 and revised with the description of additional species by Resser (1935, 1938). Following examination of type material, Schwimmer (1989) criticised characters used by Resser (1938) to differentiate *Blainia*. He suggested that *Blainia* was a junior subjective synonym of *Asaphiscus* since it lacked genal spines. This claim, however, was regarded as erroneous by Bordonaro *et al.* (2013) but without detailed discussion.

An instructive morphometric analysis of material from the middle Cambrian (Miaolingian) La Laja Formation of western Argentina prompted Bordonaro *et al.* (2013) to consider *Glyphaspis* Poulsen 1927 as a junior subjective synonym of *Blainia*. Rasetti (1965) had previously commented on the similarity between

the two genera. However, Schwimmer (1989) questioned Rasetti's (1965) assignment of *Blainia buttsi* Rasetti 1965 to *Blainia*, and gave a full description of *Glyphaspis* from the Conasauga Formation of Alabama, which he considered indistinguishable from the type material of the type species described from Montana. *Glyphaspis* was proposed by Poulsen (1927) with type species *Asaphiscus(?) capella* Walcott 1916 from the Wolsey Shale of Montana, and the name has been applied widely within Laurentia (Resser 1935, 1938, 1945; Deiss 1939; Schwimmer 1989; Melzak & Westrop 1994; Sundberg 1994).

Following their synonymisation of *Blainia* and *Glyphaspis*, Bordonaro *et al.* (2013) placed some 30 previously named species in synonymy with the type species *Blainia gregaria*, which was considered to be morphologically highly variable. They illustrated numerous cranidia and pygidia from Argentina in support of their conclusions, but only in dorsal view; many are incomplete. Type material of *Blainia gregaria* (Walcott 1916) from Alabama was neither illustrated nor re-described.

Blainia gregaria was considered to be endemic to Laurentia and the Precordilleran terrane Cuyania by Bordonaro *et al.* (2013). Greenland species referred to *Glyphaspis* by Poulsen (1927) and V. Poulsen (1964) were placed in synonymy with *Blainia gregaria* by Bordonaro *et al.* (2013). *Glyphaspis perconcava* was proposed by Poulsen (1927) for a single cranidium and a few pygidia from boulders of the Cape Wood Formation of Inglefield Land (Fig. 1A, locality 2). Its assignment to *Glyphaspis* was accepted by Schwimmer (1989). Valdemar Poulsen (1964) reported numerous cranidia and pygidia of *Glyphaspis perconcava* from J.C. Troelsen's collections from Inglefield Land but did not re-describe or illustrate further material. However, he did describe *Glyphaspis parkensis* Rasetti 1951, originally described from the Stephen Formation (*Bathyriscus*–*Elrathina* Biozone) of British Columbia, represented by cranidia and pygidia occurring together with *Glyphaspis perconcava* (V. Poulsen 1964, pl. 3, figs 8,9). On this basis, he changed the suggested age determination made by Poulsen (1927) of its occurrence from *Glossopleura* Biozone to *Bathyriscus*–*Elrathina* Biozone (V. Poulsen 1964, p. 52).

The rare Telt Bugt material contributes little to the discussion concerning the proposed synonymy of *Blainia* and *Glyphaspis*, which is followed herein only with some reservation. In the absence of information concerning morphological variation of the type material, and within most of the individual assemblages of the material synonymised by Bordonaro *et al.* (2013), the extent of the suggested synonymies with *Blainia gregaria* is left in abeyance.

***Blainia* sp.**

Figure 4K,L,N–Q

Figured material. Cranidia: PMU 35710–PMU 35712. All from GGU sample 212813, Telt Bugt Formation, Telt Bugt, Daugaard-Jensen Land.

Discussion. One of two well preserved cranidia placed here (Fig. 4P) closely resembles the specimen illustrated by Deiss (1939, pl. 16, fig. 22) as *Glyphaspis dearbornensis*, corresponding to cranidial morphotype 2 in *Blainia gregaria* of Bordonaro *et al.* (2013, fig. 3; fig. 6,1–2). The frontal area is spatulate, with the preglabellar field and border corresponding to half the length of the glabella, excluding occipital ring, which is about one quarter longer (sag.) than its maximum transverse width (Fig. 4P). The occipital ring is trapezoidal in shape, with a small, elongate, median node; fine granulation is present on the posterior glabella and interocular areas, and on the occipital ring.

The second specimen appears to have a much shorter frontal area in dorsal view (Fig. 4Q) and a more equidimensional glabella due to the greater posterior–anterior curvature of the glabella. However, the preglabellar field is of similar length in both specimens (Fig. 4N,O), although the flatness of the border varies, as does the vaulting of the glabella. A third, flattened, specimen has less strongly diverging anterior sutures and more prominent glabellar furrows (Fig. 4L).

Deiss (1939) described *Glyphaspis dearbornensis* from the Steamboat Limestone (Marjuman Stage), of Dearborn Canyon, Montana. The specimen illustrated by Bordonaro *et al.* (2013) is from the upper La Laja Formation (Marjuman Stage, *Bolaspidea* Biozone; Mialongian, Drumian Stage) at quebrada de Zonda in the Precordillera of western Argentina.

Genus *Blainiopsis* Poulsen 1946

Type species. *Blainiopsis holtedahli* Poulsen 1946 from the Cape Wood Formation (Mialongian) of Bache Peninsula, Nunavut (Fig. 1A, locality 3).

Discussion. Poulsen (1946) described three new species of *Blainiopsis* from the Cape Wood Formation of Bache Peninsula, noting that J.C. Troelsen recognised the horizon also in Inglefield Land. Valdemar Poulsen (1964) reported *Blainiopsis holtedahli* and *Blainiopsis benthami* Poulsen 1946 from west of Blomsterbækken in Inglefield Land (Fig. 1A, locality 2) but made no comment other than indicating a late *Bathyriscus*–*Elrathina* Biozone age for the upper Cape Wood Formation.

Poulsen (1946) noted that *Blainiopsis holtedahli* was known from a great number of cranidia associated

with other sclerites in the material from Bache Peninsula, whereas *Blainiopsis benthami* was represented only by a single cranidium and a few pygidia. Valdemar Poulsen (1964) recorded a few cranidia of both species from Inglefield Land. About ten specimens of *Blainiopsis* are present in GGU sample 212814 from the Telt Bugt Formation in Daugaard-Jensen Land. Both species seem to be present but the small size of the sample does not permit a meaningful assessment of variation. Elsewhere, *Blainiopsis* has been recorded from Eddie's Cove in western Newfoundland (Boyce 1979) and from the Cambrian of San Juan, Argentina (Bordonaro 1980).

***Blainiopsis holtedahli* Poulsen 1946**

Fig. 5B,D,E,H

Blainiopsis holtedahli Poulsen 1946, p. 313–314, pl. 19, figs 10–15.

Figured material. Cranidia: PMU 35715, PMU 35716. Both from GGU sample 212814, Telt Bugt Formation, Telt Bugt, Daugaard-Jensen Land (Fig. 1A, locality 4).

Discussion. The main morphological features of this species were fully described by Poulsen (1946); it is represented by five cranidia in GGU sample 212814 that are associated with indeterminate fragments of several pygidia, although it is not known if they belong to this species. Characteristic features of the cranidium include the border of relatively uniform width, the tapering glabella with almost straight sides and the straight-sided, inward curving, anterior portion of the facial sutures between the periphery and the eye (Fig. 5B,E). The two anterior pairs of glabellar furrows are broad and shallow, petaloid in form. The furrows in the posteriormost pair are complex with several bifurcations (Fig. 5B, coloured black in inset). Two branches approach the slightly arched median

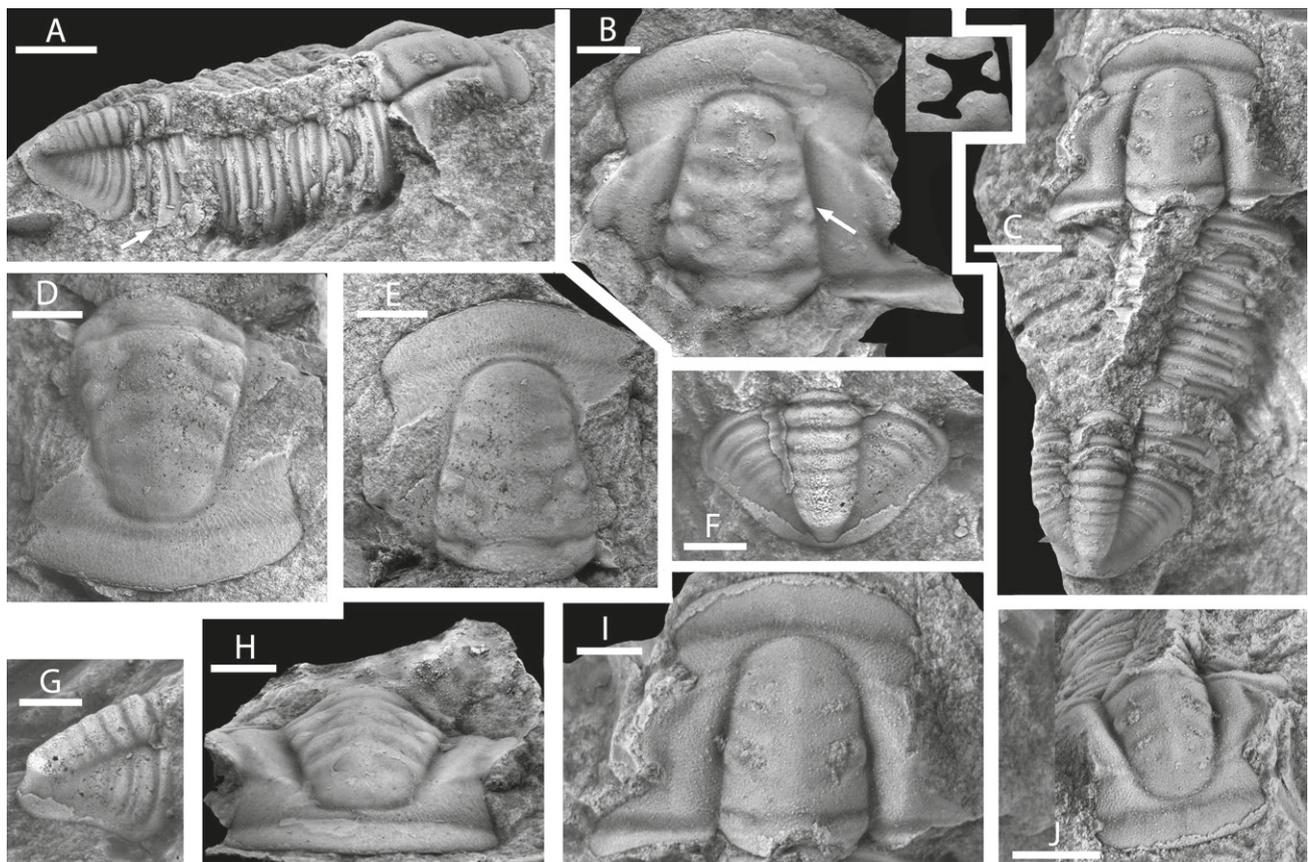


Fig. 5. *Blainiopsis* from the Telt Bugt Formation (Miaolingian) of Daugaard-Jensen Land. All specimens from GGU sample 212814. Specimens coated with black colloidal carbon and then whitened with ammonium chloride sublimate prior to photography. Scale bars are 2 mm. **A,C,F,G,I,J:** *Blainiopsis benthami* Poulsen 1946. **A,C,I,J:** PMU35713, articulated exoskeleton, lacking free cheeks and with damaged thorax, in oblique lateral (A), dorsal (C) and oblique anterior (J) views, with detail of cranidium (I); arrow in A locates a pointed pleural segment. **F,G:** PMU 35714, exfoliated pygidium in dorsal (F) and oblique lateral (G) views. **B,D,E,H:** *Blainiopsis holtedahli* Poulsen 1946. **B,H:** PMU 35715, latex cast from external mould of cranidium in dorsal (B) and anterior (H) views; arrow in B indicates the pillar-like abaxial margin of the glabellar lobe, while the inset shows the extent of the glabellar furrow (blackened). **D,E:** PMU 35716, fragment of cranidium in antero-dorsal (D) and dorsal (E) views.

line of the glabella but the posteriormost of these bifurcates; an additional branch is directed back towards the axial furrow, isolating the abaxial portion of the lobe as a discrete pillar (arrow in Fig. 5B). The occipital furrow is complete, but with deep pits at the adaxial end of the deepened lateral portions.

Ornamentation consists of granules on the glabella which are coarsest on the occipital ring but absent from the anterior extremity. Fine, weakly anastomosing ridges radiate from the anterior part of the eye ridges and glabella towards the anterior margin with the pattern becoming increasingly cellular at the margin (Fig. 5D,E).

The cranidium of *Blainiopsis holtedahli* is similar to that of *Clappaspis tupeq* in its overall shape, the degree of tapering of the conical glabella and the narrow preglabellar field. The border furrow is straight (trans.) in the latter, however, while curved in *Blainiopsis holtedahli*. Pygidia of *Clappaspis tupeq* (Fig. 4A,D,I) are shorter (sag.) than in *Blainiopsis* (Poulsen 1946, pl. 19, fig. 15; Fig. 5F), with the bluntly rounded termination of the axis stopping well short of the posterior border.

***Blainiopsis benthami* Poulsen 1946**

Fig. 5A,C,F,G,I,J

Blainiopsis benthami Poulsen 1946, p. 314–315, pl. 19, fig. 16, pl. 20, figs 1–2.

Figured material. Partial specimen: PMU 35713. Pygidium: PMU 35714. Both from GGU sample 212814, Telt Bugt Formation, Telt Bugt, Daugaard-Jensen Land (Fig. 1A, locality 4).

Discussion. *Blainiopsis benthami* is represented in GGU sample 212814 by an almost complete specimen, lacking free cheeks and with the thorax damaged (Fig. 5A,C), and an isolated pygidium (Fig. 5F,G). It is distinguished from the type species, *Blainiopsis holtedahli*, by the greater curvature of the anterior margin, producing more pronounced lateral tapering of the border, and the anterior part of the facial suture curving convexly in to meet the eye ridge. This segment of the suture is straight in *B. holtedahli* (Fig. 5B,E). Palpebral lobes and the broad furrow forming their adaxial margin are more strongly curved in dorsal view than in *B. holtedahli*; the eye ridges are closer to the anterior margin and less oblique to the sides of the glabella (Fig. 5C,I,J). The glabella has shallowly convex sides and is less conical in form than the strongly tapering glabella of *B. holtedahli*.

A deep, wide, medial pleural furrow on segments in the thorax terminates abruptly just prior to the pointed, but not spinose, abaxial margin (arrow in Fig. 5A). Pleural and interpleural furrows are promi-

nent on the anterior part of the pleural areas of the pygidium but fade towards the posterior; anterior and posterior fields of the pleurae are uniform in width but unequal in length (sag.). Poulsen (1946) noted that furrowing in *B. holtedahli* was well developed throughout the pleural area. Lateral margins of the pygidium are shallowly concave, slightly arched, at about the level of the second segment (Fig. 5G).

Ornamentation consists of a very fine granulation that is slightly coarser near the occipital furrow and on the posterior fixed cheeks. Weakly anastomosing radial ridges on the frontal area are much less strongly developed than in *B. holtedahli* (Fig. 5I).

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References

- Babcock, L.E. 1994: Systematics and phylogenetics of polymeroid trilobites from the Henson Gletscher and Kap Stanton formations (Middle Cambrian), North Greenland. *Bulletin Grønlands Geologiske Undersøgelse* 169, 79–127.
- Babcock, L.E., Robison, R.A. & Peng, S. 2011: Cambrian stage and series nomenclature of Laurentia and the developing global chronostratigraphic scale. In: Hollingsworth, J.S., Sundberg, F.A., & Foster, J.R. (eds), *Cambrian stratigraphy and paleontology of northern Arizona and southern Nevada*, The 16th field conference of the Cambrian Stage Subdivision Working Group, International Subcommittee on Cambrian Stratigraphy. Flagstaff, Arizona, and southern Nevada, United States. *Museum of Northern Arizona Bulletin* 67, 12–26.
- Bordonaro, O.L. 1980: El Cámbrico en la quebrada de Zonda, provincia de San Juan. *Revista de la Asociación Geológica Argentina* 35, 26–40.
- Bordonaro, O.L., Pratt, B.R. & Robledo, V. 2013: Systematic, morphometric and palaeobiogeographic study of *Blainia gregaria* Walcott, 1916 (Trilobita, Ptychopariida), Middle Cambrian of the Precordillera of western Argentina. *Geological Journal* 48, 126–141. <https://doi.org/10.1002/gj.1344>
- Boyce, W.D. 1979: Further developments in western Newfoundland Cambro-Ordovician biostratigraphy. Newfoundland Department of Mines and Energy, Mineral Development

- Division, Report of Activities for 1979, Report 1979-1, 7-9.
- Christie, R.L. 1967: Bache Peninsula, Ellesmere Island, Arctic Archipelago. Geological Survey of Canada, Memoir 347, 63 pp. <https://doi.org/10.4095/100534>
- Cooper, G.A., Arellano, A.R.V., Johnson, J.H., Okulitch, V.J., Stoyanow, A. & Lochman, C. 1952: Cambrian stratigraphy and paleontology near Caborca, northwestern Sonora, Mexico. *Smithsonian Miscellaneous Collections* 119, 1, 184 pp.
- Dawes, P.R. 1976: Precambrian to Tertiary of northern Greenland. In: Escher, A. & Watt, W.S. (eds), *Geology of Greenland*, 248-303. Geological Survey of Greenland, Copenhagen.
- Dawes, P.R. 2004: Explanatory notes to the geological map of Greenland, 1:500 000 Sheet 6 Humboldt Gletscher. Geological Survey of Denmark and Greenland Map Series 1, 48 pp.
- Dawes, P.R. *et al.* 2000: Kane Basin 1999: mapping, stratigraphic studies and economic assessment of Precambrian and Lower Palaeozoic provinces in north-western Greenland. *Geology of Greenland Survey Bulletin* 186, 11-28.
- de Freitas, T. 1998a: New observations on the geology of eastern Ellesmere Island, Canadian Arctic, part II: Cambro-Ordovician stratigraphy of the Parrish Glacier region. *Geological Survey of Canada, Current Research 1998-E*, 31-40.
- de Freitas, T. 1998b: New observations on the geology of eastern Ellesmere Island, Canadian Arctic, Part IV: Cambro-Ordovician stratigraphy of the Rawlings Bay area and nunataks of the Agassiz Ice Cap. *Geological Survey of Canada, Current Research 1998-E*, 51-61. <https://doi.org/10.4095/209951>
- Deiss, C.F. 1939: Cambrian stratigraphy and trilobites of north-western Montana. *Geological Society of America, Special Papers* 18, 135 pp. <https://doi.org/10.1130/spe18-p1>
- Dewing, K., Harrison, J.C. & Mayr, U. 2001: Stratigraphy of the Cass Fjord Formation (Middle and Upper Cambrian), northeast Ellesmere Island, Nunavut. *Geological Survey of Canada, Current Research 2001-B4*, 23 pp. <https://doi.org/10.4095/212118>
- Fritz, W.H. 1968: Lower and early Middle Cambrian trilobites from the Pioche Shale, east central Nevada, USA. *Palaeontology* 11, 183-235.
- Geyer, G. & Peel, J.S. 2011: The Henson Gletscher Formation, North Greenland, and its bearing on the global Cambrian Series 2 - Series 3 boundary. *Bulletin of Geosciences* 86, 465-534. <https://doi.org/10.3140/bull.geosci.1252>
- Geyer, G. & Peel, J.S. 2017: Middle Cambrian trilobites from the Ekspedition Bræ Formation of North Greenland, with a reappraisal of the genus *Elrathina*. *Journal of Paleontology* 91, 265-293. <https://doi.org/10.1017/jpa.2016.152>
- Hall, J. & Whitfield, R.P. 1877: Paleontology, Part 2. United States Geological Survey Exploration along the 40th parallel, Report 4, 197-302.
- Harrington, H.J. *et al.* 1959: Arthropoda 1. In: Moore, R.C. (ed.), *Treatise on Invertebrate Paleontology part O*, 560 pp. Geological Society of America and University of Kansas Press. <https://doi.org/10.17161/dt.v0i0.5604>
- Henriksen, N. & Peel, J.S. 1976: Cambrian-Early Ordovician stratigraphy in south-western Washington Land, western North Greenland. *Rapport Grønlands Geologiske Undersøgelse* 80, 17-23.
- Higgins, A.K., Ineson, J.R., Peel, J.S., Surlyk, F. & Sønderholm, M. 1991: Lower Palaeozoic Franklinian Basin of North Greenland. *Grønlands Geologiske Undersøgelse Bulletin* 160, 71-139.
- Holtedah, O. 1913: The Cambro-Ordovician beds of Bache Peninsula and the neighbouring regions of Ellesmere Land. Report of the Second Norwegian Arctic Expedition in the 'Fram' 1898-1902 28, 1-14.
- Ineson, J.R., & Peel, J.S. 1997: Cambrian shelf stratigraphy of North Greenland. *Geology of Greenland Survey Bulletin* 173, 120 pp.
- Kobayashi, T. 1935: The Cambro-Ordovician formations and faunas of South Chosen. *Paleontology*, pt. III. Cambrian faunas of South Chosen with special study on the Cambrian trilobite genera and families. *Journal Faculty of Science Imperial University of Tokyo* 4, 49-344.
- Lochman, C. & Hu, C. 1960: Upper Cambrian faunas from the northwest Wind River Mountains, Wyoming, Part 1. *Journal of Paleontology* 34, 793-834. <https://www.jstor.org/stable/1301009>
- McCollum, L.B. & Sundberg, F.A. 2007: Cambrian trilobite biozonation of the Laurentian Delamaran Stage in the southern Great Basin, U.S.A.: implications for global correlations and defining a Series 3 global boundary stratotype. *Memoirs of the Association of Australasian Palaeontologists* 34, 147-156.
- Meek, F.B. 1873: Paleontology. United States Geological Survey Exploration along the 40th parallel, Report 4, 1-197.
- Melzak, A. & Westrop, S.R. 1994: Mid-Cambrian (Marjuman) trilobites from the Pika Formation, southern Canadian Rocky Mountains, Alberta. *Canadian Journal of Earth Sciences* 31, 969-985. <https://doi.org/10.1139/e94-086>
- Miller, B.M. 1936: Cambrian trilobites from north-western Wyoming. *Journal of Paleontology* 10, 35-43.
- Palmer, A.R. 1954: An appraisal of the Great Basin Middle Cambrian trilobites described before 1900. *United States Geological Survey Professional Paper* 264-D, 53-86. <https://doi.org/10.3133/pp264d>
- Palmer, A.R. & Halley, R.B. 1979: Physical stratigraphy and trilobite biostratigraphy of the Carrara Formation (Lower and Middle Cambrian) in the southern Great Basin: *United States Geological Survey Professional Paper* 1047, 131 pp. <https://doi.org/10.3133/pp1047>
- Palmer, A.R. & Peel, J.S. 1981: Dresbachian trilobites and stratigraphy of the Cass Fjord Formation, western North Greenland. *Bulletin Grønlands Geologiske Undersøgelse* 141, 46 pp.
- Peel, J.S. (ed.) 1994: Palaeontology, stratigraphy and environmental setting of Middle Cambrian outer shelf deposits, North Greenland. *Bulletin Grønlands Geologiske Undersøgelse* 169, 155 pp.
- Peel, J.S. 2011: Olenelloid trilobites from Cambrian Series 2 of Devon Island, Nunavut, Arctic Canada. *Canadian Journal of Earth Sciences* 48, 1471-1482. <https://doi.org/10.1139/e11-048>
- Peel, J.S. 2020: *Polypleuraspis* (Arthropoda, Trilobita) from the

- middle Cambrian (Miaolingian Series) around Kane Basin (Nunavut and Greenland). *Canadian Journal of Earth Sciences* 57, 16–24. <https://doi.org/10.1139/cjes-2019-0011>
- Peel, J.S. & Christie, R.L. 1982: Cambrian–Ordovician platform stratigraphy: correlations around Kane Basin. *Meddelelser om Grønland, Geoscience* 8, 117–135.
- Poulsen, C. 1927: The Cambrian, Ozarkian, and Canadian faunas of northwest Greenland: *Meddelelser om Grønland* 70, 233–343.
- Poulsen, C. 1934: The Silurian faunas of North Greenland. I. The fauna of the Cape Schuchert Formation. *Meddelelser om Grønland* 72, 2(1), 46 pp.
- Poulsen, C. 1941: The Silurian faunas of North Greenland. II. The fauna of the Offley Island Formation. Part I Coelenterata. *Meddelelser om Grønland* 72, 2(2), 28 pp.
- Poulsen, C. 1943: The Silurian faunas of North Greenland. II. The fauna of the Offley Island Formation. Part II Brachiopoda. *Meddelelser om Grønland* 72, 2(3), 60 pp.
- Poulsen, C. 1946: Notes on Cambro-Ordovician fossils collected by the Oxford University Ellesmere Land expedition 1934–5. *Quarterly Journal of the Geological Society of London* 102, 299–337. <https://doi.org/10.1144/gsl.jgs.1946.102.01-04.15>
- Poulsen, C. 1958: Contribution to the palaeontology of the Lower Cambrian Wulff River formation. *Meddelelser om Grønland* 162, 27 pp.
- Poulsen, V. 1964: Contribution to the Lower and Middle Cambrian palaeontology and stratigraphy of Northwest Greenland. *Meddelelser om Grønland* 164, 105 pp.
- Rasetti, F. 1951: Middle Cambrian stratigraphy and faunas of the Canadian Rocky Mountains. *Smithsonian Miscellaneous Collections* 116, 277 pp.
- Rasetti, F. 1965: Middle Cambrian trilobites of the Pleasant Hill Formation in Central Pennsylvania. *Journal of Paleontology* 39, 1007–1014. <https://www.jstor.org/stable/3555318>
- Raymond, P.E. 1924: New Upper Cambrian and Lower Ordovician trilobites from Vermont. *Proceedings of the Boston Society of Natural History* 37, 389–466.
- Resser, C.E. 1935: Nomenclature of some Cambrian trilobites. *Smithsonian Miscellaneous Collections* 93, 5, 46 pp.
- Resser, C.E. 1937: Third contribution to nomenclature on Cambrian trilobites. *Smithsonian Miscellaneous Collections* 93, 22, 59 pp.
- Resser, C.E. 1938: Cambrian system (restricted) of the Southern Appalachians. *Geological Society of America, Special Papers* 15, 140 pp. <https://doi.org/10.1130/spe15>
- Resser, C.E. 1939a: The Spence Shale and its fauna. *Smithsonian Miscellaneous Collections* 97, 12, 29 pp.
- Resser, C.E. 1939b: The Ptarmigania strata of the northern Wasatch Mountains. *Smithsonian Miscellaneous Collections* 98, 72 pp.
- Resser, C.E. 1945: Cambrian fossils of the Grand Canyon. In: McKee, E.D. & Resser, C.E. (eds), *Cambrian history of the Grand Canyon*, 169–220. Carnegie Institution, Washington.
- Richter, R. 1933: Crustacea (Paläontologie) *Handwörterbuch der Naturwissenschaften*, 2nd edition 2, 840–864.
- Robison, R.A. 1964: Late Middle Cambrian faunas from western Utah. *Journal of Paleontology* 38, 510–566. <https://www.jstor.org/stable/1301528>
- Robison, R.A. 1988: Trilobites of the Holm Dal Formation (late Middle Cambrian), central North Greenland. *Meddelelser om Grønland, Geoscience* 20, 23–103.
- Robison, R.A. 1994: Agnostoid trilobites from the Henson Gletscher and Kap Stanton formations (Middle Cambrian), North Greenland. *Bulletin Grønlands Geologiske Undersøgelse* 169, 25–77.
- Schwimmer, D.R. 1989: Taxonomy and biostratigraphic significance of some Middle Cambrian trilobites from the Conasauga Formation in western Georgia. *Journal of Paleontology* 63, 484–494. <https://doi.org/10.1017/S0022336000019703>
- Sundberg, F.A. 1994: Corynexochida and Ptychopariida (Trilobita, Arthropoda) of the *Ehmaniella* Biozone (Middle Cambrian), Utah and Nevada. *Natural History Museum of Los Angeles County, Contributions in Science* 446, 137 pp.
- Sundberg, F.A. 2005: The Topazan Stage, a new Laurentian stage (Lincolnian Series—“Middle” Cambrian). *Journal of Paleontology* 79, 63–71. [https://doi.org/10.1666/0022-3360\(2005\)079<0063:ttsanl>2.0.co;2](https://doi.org/10.1666/0022-3360(2005)079<0063:ttsanl>2.0.co;2)
- Sundberg, F.A. 2018: Trilobite biostratigraphy of the Cambrian 5 and Drumian stages, Series 3 (Laurentian Delamaran, Topazan, and Marjuman stages, Lincolnian Series) of the lower Emigrant Formation at Clayton Ridge, Esmeralda County, Nevada. *Journal of Paleontology* 92, *Memoir* 76, 44 pp. <https://doi.org/10.1017/jpa.2017.130>
- Swinnerton, H.H. 1915: Suggestions for a revised classification of trilobites. *Geological Magazine, new series* 2, 487–496. <https://doi.org/10.1017/S0016756800203634>
- Troedsson, G.T. 1926: On the Middle and Upper Ordovician faunas of northern Greenland. I. Cephalopods. *Meddelelser om Grønland* 71, 1, 157 pp.
- Troedsson, G.T. 1928: On the Middle and Upper Ordovician faunas of northern Greenland. Part II. *Meddelelser om Grønland* 72, 1(1), 197 pp.
- Troelsen, J.C. 1950: Contributions to the geology of Northwest Greenland, Ellesmere Island and Axel Heiberg Island. *Meddelelser om Grønland* 149, 86 pp.
- Walch, J.E.I. 1771: *Die Naturgeschichte der Versteinerungen, zur Erläuterung der Knorr’schen Sammlung von Merkwürdigkeiten der Natur*, 4, 3, 184 pp. Paul Jonathan Felstecker, Nürnberg.
- Walcott, C.D. 1889: Description of new genera and species of fossils from the Middle Cambrian. *U. S. National Museum Proceedings* 11, 441–446. <https://doi.org/10.5479/si.00963801.11-738.441>
- Walcott, C.D. 1916: Cambrian geology and paleontology III, no. 5, Cambrian trilobites. *Smithsonian Miscellaneous Collections* 64, 303–456.
- Watt, W.S. 2019: Stratigraphic lexicon for Greenland. Nomenclature of stratified successions in current use, 327 pp. *Geological Survey of Denmark and Greenland, Copenhagen*. <https://doi.org/10.22008/geusbook/strat-lex-greenland>