An outer shelf shelly fauna from Cambrian Series 2 (Stage 4) of North Greenland (Laurentia)

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Abstract.—An assemblage of 50 species of small shelly fossils is described from Cambrian Series 2 (Stage 4) strata in North Greenland, the present day northernmost part of the paleocontinent of Laurentia. The fossils are derived from the basal member of the Aftenstjernesø Formation at Navarana Fjord, northern Lauge Koch Land, a condensed unit that accumulated in a sediment-starved outer ramp setting in the transarctic Franklinian Basin, on the Innuitian margin of Laurentia. Most other small shelly fossil assemblages of similar age and composition from North America are described from the Iapetan margin of Laurentia, from North-East Greenland south to Pennsylvania. Trilobites are uncommon, but include *Serrodiscus*. The Australian bradoriid *Spinospitella* is represented by a complete shield. *Obolella crassa* is the only common brachiopod. Hyoliths, including *Cassitella*, *Conotheca*, *Neogloborilus*, and *Triplicatella*, are abundant and diverse, but most are represented just by opercula. Sclerites interpreted as stem-group aculiferans (sachitids) are conspicuous, including *Qaleruaqia*, the oldest described paleoloricate, *Ocruranus*?, *Inughuitoconus* n. gen., and *Hippopharangites*. Helcionelloid mollusks are diverse, but not common; they are associated with numerous specimens of the bivalve *Pojetaia runnegari*. The fauna compares best with that of the upper Bastion Formation of North-East Greenland, the Forteau Formation of western Newfoundland, and the Browns Pond Formation of New York, but several taxa have a world-wide distribution. Many specimens are encrusted with crystals of authigenic albite. New species: *Anabarella*? *navaranae*, *Stenotheca*? *higginsi*, *Figurina*? *polaris*, *Hippopharangites groenlandicus*, *Inughuitoconus borealis*, and *Ocruranus*? *kangerluk*.

UUID: http://zoobank.org/160a17b1-3166-4fcf-9849-a3cabd1e04a3

Introduction

North Greenland is the northernmost land mass on earth, reaching almost to 83°40′N, and yields the northernmost assemblages of Cambrian fossils. Cambrian paleogeography, however, was markedly different, with the present high arctic terrane lying just south of the equator on the eastern side of the Laurentian paleocontinent (Torsvik and Cocks, 2016). The record of this equatorial history persists in the extensive Cambrian (Cambrian Series 2–Furongian) fossil assemblages that have been described from carbonate-dominated sections in northern Greenland in the century that has elapsed since Cambrian fossils were first collected by the Danish polar explorer and geologist Lauge Koch (1882–1964) from Inglefield Land (Poulsen, 1927; Christie and Dawes, 1991; Fig. 1.3).

Northern Greenland preserves an extensive Cambrian (Series 2–Furongian) record with southern, carbonate-dominated shelf sediments and a northern deep-water trough succession, in terms of present day geography (Higgins et al., 1991a, b). The present paper, however, documents the diverse fauna of just a single horizon from North Greenland: a thin unit recording the initiation of carbonate sedimentation on the shelf during Cambrian Stage 4 following the earlier transgression by siliciclastic sediments (Fig. 1.4, 1.5). This unique horizon, the basal member of the Aftenstjernesø Formation, is typically only 3–5 m in thickness, but it can be traced over a distance of 200 km east–west from southern Peary Land to southern Freuchen Land, and 50 km south–north from southern Lauge Koch Land to its northern shore (Fig. 1.1, 1.3). Its value in a regional context is that its distinctive lithology and fauna facilitate linkage between Cambrian stratigraphic successions in the separate southern and northern successions.

The fossil assemblages described herein are derived from the eastern side of Navarana Fjord, northern Lauge Koch Land, near the northern limit of the Aftenstjernesø Formation (Fig. 1.1, 1.5). They provide a point of reference close to the outer margin of the shelf for comparisons with equivalent, but as yet largely undescribed faunas from the same member in the prograding inner shelf environments to the south, in southern Freuchen Land, southern Lauge Koch Land, and across southern Peary Land (Fig. 1.1, 1.3). In a broader context, the fossil assemblage supports Cambrian Stage 4 correlations elsewhere in Greenland and Laurentia, and beyond into other paleocontinents.

Geological background

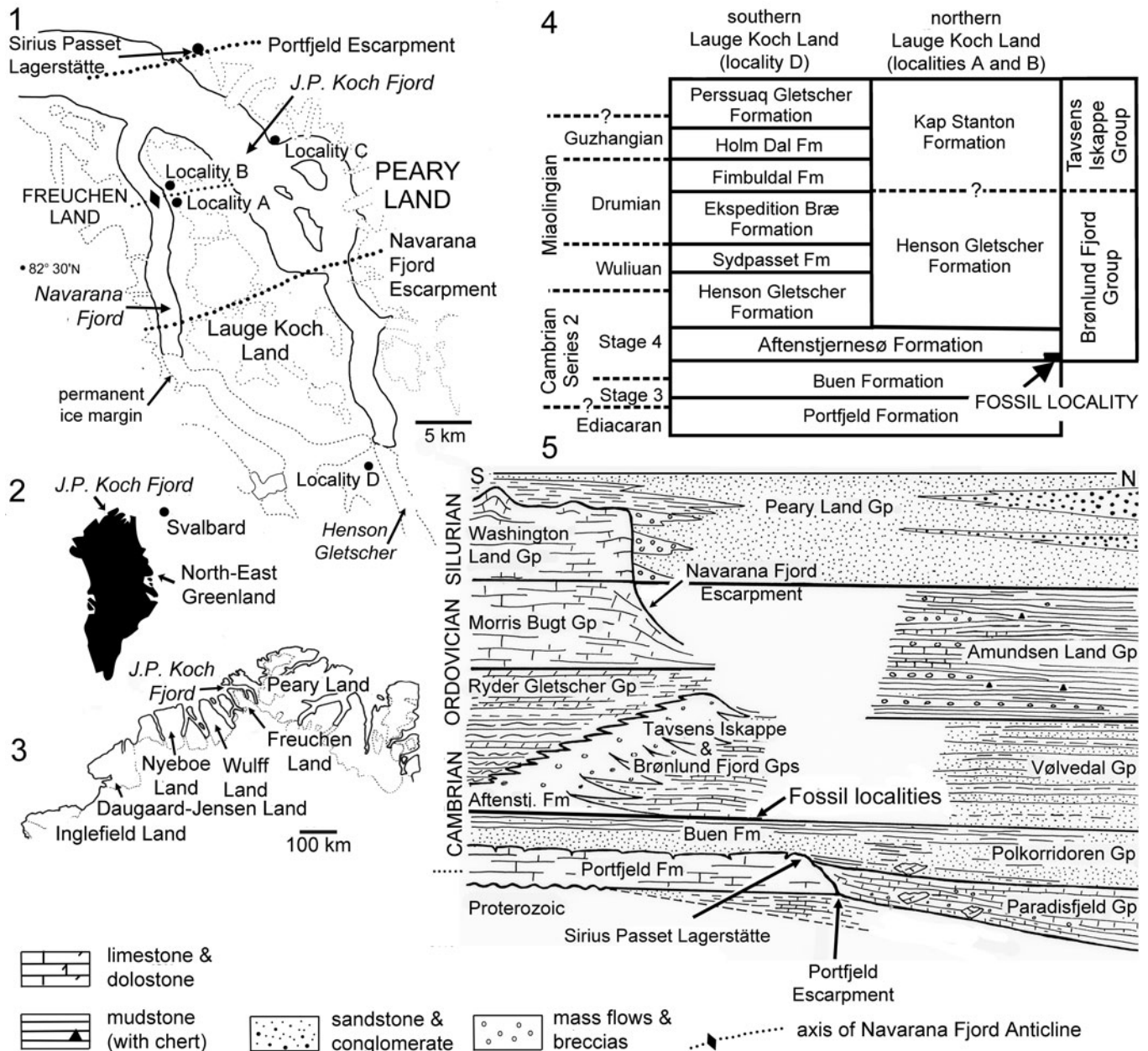Cambrian sediments in northern Greenland crop out in three main areas. Following transgression by lower Cambrian

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Figure 1. Geographical and geological background. (**1**) Collection localities: Localities A (GGU samples 313012 and 315028) and B (GGU samples 315043 and 315045) in northern Lauge Koch Land, North Greenland; Locality C yields Miaolingian trilobites of Baltic aspect described by Babcock (1994a, b) from the Kap Stanton Formation; Locality D is type locality of the Aftenstjernesø Formation in southern Lauge Koch Land (Ineson and Peel, 1997); (**2**) Greenland showing location of present study area (**1**) and Cambrian outcrops in Svalbard and North-East Greenland; (**3**) land areas in northern Greenland; (**4**) Cambrian stratigraphy in the Lauge Koch Land area, North Greenland. The Ediacaran age of the lower Portfjeld Formation was recently established by Willman et al. (2020). (**5**) Schematic cross-section through the Franklinian Basin of North Greenland, based on Higgins et al. (1991a), showing fossil localities at the northern limit of the Aftenstjernesø Formation. The traces of the two principal structural elements (Navarana Fjord Escarpment and Portfjeld Escarpment) are shown in (**1**).

siliciclastic sediments, the classic area of Inglefield Land and adjacent Daugaard-Jensen Land (Fig. 1.3) is dominated by inner shelf carbonates. Olenelloid assemblages of Cambrian Stage 4 (Poulsen, 1927, 1958, 1964; Lieberman, 1999) are followed by Miaolingian Series (Wuliuan Stage) and Furongian Cambrian faunas typical of the Laurentian inner carbonate shelf (Poulsen, 1927, 1964; Palmer and Peel, 1981; Peel, 2020a, b, 2021).

An eastern belt extending from southern Wulff Land across southern Peary Land also commences with transgressive siliciclastic sediments (Fig. 1.3–1.5; Buen Formation), but these

are followed by a complex of shelf carbonates (Brønlund Fjord and Tavsens Iskappe groups; Fig. 1.4, 1.5) that prograde northward, out across the open shelf (Higgins et al., 1991a, b; Ineson and Peel, 1997). The Buen Formation yields rich Cambrian Stage 3–Stage 4 faunas (Peel and Willman, 2018) before carbonate sedimentation commences in Stage 4, small shelly fossils from which are described herein. Diverse open shelf faunas culminate in a well-developed late Stage 4 *Ovatoryctocara granulata* assemblage (Blaker and Peel, 1997; Geyer and Peel, 2011; Peel et al., 2016), followed by Miaolingian faunas that combine elements of the Laurentian inner shelf fauna with

open shelf agnostid assemblages (Robison, 1988; Geyer and Peel, 2017).

Along the northern coast, from northern Nyeboe Land to Peary Land (Fig. 1.3), outer shelf and deep-water trough successions re-emerge from beneath a cover of Ordovician and Silurian strata as a result of middle Paleozoic Ellesmerian orogenesis (Higgins et al., 1991a, b). The northern coast successions in Nyeboe Land (Fig. 1.3) are characterized by the trilobite *Serrodiscus* Richter and Richter, 1941 (Blaker and Peel, 1997; Peel and Skovsted, in press). The Sirius Passet Lagerstätte (Cambrian Series 2, Stage 3) from the lower Buen Formation in western Peary Land (Fig. 1.1, 1.5) requires special mention as the most significant Cambrian discovery from North Greenland, representing the oldest major Cambrian lagerstätte from Laurentia (Conway Morris et al., 1987; Conway Morris and Peel, 1995; Ineson and Peel, 2011; Peel and Ineson, 2011a, b; Botting and Peel, 2016; Harper et al., 2019). This unique locality with exceptionally preserved fossils lies 12 km to the north of the fossiliferous localities described herein (Fig. 1.1, 1.5) and was deposited just offshore from the outer degraded edge of the carbonate platform of the Portfjeld Formation, which underlies the more southerly Cambrian successions (Fig. 1.5).

Series 2 strata in northern Nyeboe Land are followed by Laurentian shelf faunas, but the Miaolingian in northwestern Peary Land (Fig. 1.1, locality C) preserves faunas of Baltic aspect (Babcock, 1994a, b; Robison, 1994). Babcock (1994b) proposed that this difference indicated the presence of a thermocline in Miaolingian strata in North Greenland, with warmer water shelf faunas of Laurentian aspect overlying faunas of Baltic aspect in a cooler, deeper water, outer shelf environment. Thus, typically middle to high latitude, shallow water, Baltic faunas were present at depth in the low latitudes occupied by North Greenland during the Cambrian, emphasizing that the faunal aspect was not governed by latitude differences alone (Babcock, 1994b).

The sedimentological dynamics of this profound faunal differentiation are magnificently exposed along the sheer sides of J.P. Koch Fjord (Higgins et al., 1991a, b; Ineson et al., 1994; Ineson and Peel, 1997; Fig. 1.1, 1.5) that preserve a cross-section through this margin of the transarctic Franklinian Basin. Inner shelf and prograding platform margin sediments in southern Lauge Koch Land pass through areas of outer shelf deposition to deep-water trough sedimentation in northernmost Lauge Koch Land (Fig. 1.1, 1.4, 1.5).

All material described herein was collected from the Aftenstjernesø Formation from outcrops on the eastern side of Navarana Fjord (Fig. 1.1, localities A and B). The Aftenstjernesø Formation is the basal formation in a Cambrian–Early Ordovician, carbonate-dominated, prograding sedimentary complex referred to the Brønlund Fjord and Tavsens Iskappe groups (Fig. 1.4, 1.5; Higgins et al., 1991a, b; Ineson et al., 1994; Ineson and Peel, 1997). The progradation reflects a deepening trend that is coeval with eustatic deepening along the present day eastern shore of Laurentia (Landing, 2012), but was also related to early Caledonide accretion along the same margin by Surlyk (1991) and Higgins et al. (1991a). In southern Lauge Koch Land and adjacent western Peary Land, the complex consists of an alternation of cliff-forming prograding coarse, cross-bedded dolomitic grainstones with frequent debris flows, deposited during highstands of sea level, and recessive mudstone-limestone-dolostone units representing lowstand conditions (Higgins et al., 1991a, b; Ineson and Peel, 1997; Fig. 1.4, 1.5). This alternation of highstand and lowstand deposition promoted the establishment of a lithostratigraphic subdivision that is not applicable in northern Lauge Koch Land, where dark outer shelf mudstones and carbonates of the Henson Gletscher and Kap Stanton formations dominate the succession (Ineson et al., 1994) beyond the offshore limit of most of the prograding units (Fig. 1.4, 1.5).

The Aftenstjernesø Formation documents the initial establishment of carbonate deposition following the siliciclastic shelf sediments of the Buen Formation (Ineson and Peel, 1997; Peel and Willman, 2018; Wallet et al., 2020), which crop out extensively across central and eastern North Greenland (Ineson and Peel, 1997; Peel and Willman, 2018). The formation is dominated by cliff-forming dolostone grainstones. In its type area in southern Lauge Koch Land (Fig. 1.1, locality D), the formation attains a thickness of ∼62 m (Ineson and Peel, 1997), but this is reduced to only 18 m at the fossil collection sites in northern Lauge Koch Land (Fig. 1.1, localities A and B). In the southern Freuchen Land-southern Peary Land area, fossils from the Aftenstjernesø Formation are generally restricted to the basal few meters of nodular dolomitic grainstones that are rich in glauconite, phosphorite bioclasts, pyrite, and phosphatized hardgrounds (Frykman, 1980; Peel, 2017a). This condensed unit accumulated in a sediment-starved outer ramp setting and can be traced from southern to northern Lauge Koch Land (Fig. 1.1) and eastward across Peary Land. Its initial recognition in northern Lauge Koch Land was a key element in establishing correlation between outcrops of the Brønlund Fjord Group in southern Freuchen Land and southern Peary Land and the structurally uplifted Cambrian successions of the northern coast.

The Navarana Fjord fauna

The faunas of the individual samples described herein from the lower Aftenstjernesø Formation at Navarana Fjord (Fig. 2.2) are not closely similar to each other in detail despite their comparable stratigraphic level, suggesting that the full faunal diversity of the sediment-starved ramp deposits is not yet known. GGU samples 313012 and 315043 are probably autochthonous, but fossils in GGU samples 315028 and 315045 were transported down the shelf from the south. The basal stratum of the Aftenstjernesø Formation at locality B (Fig. 1.1) consists of pyrite-rich, brown-weathering dolostone with large tubes of *Hyolithellus* Billings, 1871 in life position (GGU sample 315043; not figured). Similar, unusually large specimens preserved in life position were described from the basal Aftenstjernesø Formation at Henson Gletscher (Fig. 1.1, locality D) by Skovsted and Peel (2011). GGU sample 313012 yielded only a single specimen—an almost complete bradoriid *Spinospitella coronata* Skovsted, Brock, and Paterson, 2006 (Figs. 2.2, 3). Only nine of the 17 species recorded from GGU sample 315028 (Figs. 2.2, 4) occur in GGU sample 315045, where 40 species were recovered (Figs. 2.2, 5–15). However, most taxa in GGU sample 315045 are represented by very few specimens, indicating a remarkable diversity in a sample of about 1.5 kg.
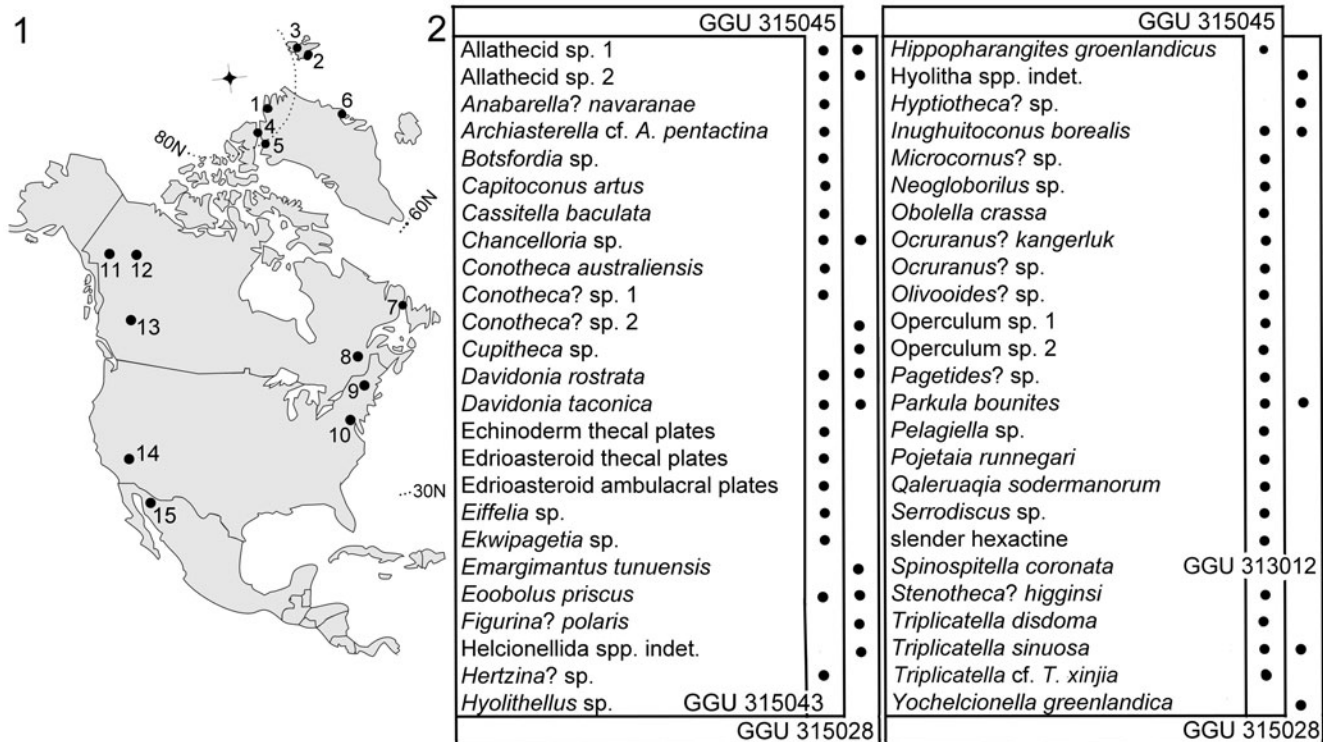
Figure 2. (**1**) Localities in North America discussed in the text. 1, J.P. Koch Fjord area (Fig. 1.1); 2, south-west Svalbard; 3, north-east Svalbard; 4, Nares Strait region (Nyeboe Land, Greenland, and Judge Daly Promontory, Ellesmere Island, Nunavut, Canada); 5, Inglefield Land, North-West Greenland; 6, North-East Greenland; 7, western Newfoundland; 8, Ville-Guay, Québec; 9, Taconic allochthon, New York State; 10, Thomasville, Pennsylvania; 11, Yukon Territory; 12, Northwest Territories; 13, Mural Formation, southwestern Canada; 14, western USA; 15, Sonora, Mexico. (**2**) Faunal list for the basal Aftenstjernesø Formation on the eastern side of Navarana Fjord, northern Lauge Koch Land (Fig. 1.1, localities A and B).

Olenelloid trilobite remains are not known from the present material, but occur in the Aftenstjernesø Formation ~10 km to the east (Fig. 1.1, locality C). Apart from the eodiscoid *Serrodiscus* sp. (Fig. 5.1–5.5), only two trilobite specimens are known from the samples from Navarana Fjord: an internal mold (Fig. 5.7, 5.8) of *Pagetides*? sp. and a single broken pygidium of *Ekwipagetia* sp. (Fig. 5.9, 5.10), the latter also known from the Kap Troedsson Formation (Cambrian Stage 4) in southern Wulff Land (Blaker and Peel, 1997; Fig. 1.3).

Apart from *Obolella crassa* (Hall, 1847) (Fig. 6), brachiopods are rare, with only two specimens of *Eoobolus priscus* (Poulsen, 1932) (Fig. 5.11, 5.12) and a single fragment of *Botsfordia* sp. (Fig. 5.13, 5.14). The cnidarian *Olivooides*? sp. (Fig. 5.15) and *Hertzina*? sp. (Fig. 6.10, 6.13) are also represented by single specimens.

The calcarean poriferan *Eiffelia* Walcott, 1920 is represented by single specimens of six-rayed (Fig. 7.1) and four-rayed sclerites from GGU sample 315045, together with common hexactin and rare pentactin sponge spicules characterized by long, slender rays (Fig. 7.11). Sclerites of *Chancelloria* Walcott, 1920 (Fig. 7.2–7.4, 7.8) are similar to *Platyspinatus* Vassiljeva, 1985. *Archiasterella* cf. *A. pentactina* Sdzuy, 1969 mainly occurs as five-rayed sclerites (Fig. 7.7, 7.9). Echinoderms are represented by a variety of thecal plates, mainly of edrioasteroids (Fig. 8.1–8.16).

Hyolith opercula are common, but conchs are rare. Internal molds of *Cupitheca* Duan in Xing et al., 1984 (Fig. 4.3) in GGU sample 315028 resemble *Cupitheca holocyclata* (Bengtson in

Bengtson et al., 1990). *Microcornus*? sp. is known from just a single specimen (Fig. 15.12).

Described originally from North-East Greenland by Malinky and Skovsted (2004), unusually robust opercula of *Cassitella baculata* are common at Navarana Fjord (Fig. 10). *Triplicatella* Conway Morris in Bengtson et al., 1990 is represented by three species (Fig. 12.1–12.11). Other opercula are referred to *Parkula bounites* Bengtson in Bengtson et al., 1990 (Fig. 9.4–9.8), *Hyptiotheca*? sp. (Fig. 4.4), *Conotheca laurentiensis* Landing and Bartowski, 1996 (Fig. 11.18–11.20), *Conotheca*? spp. 1 and 2, *Neogloborilus* Qian and Zhang, 1983 (Fig. 9.1–9.3), and allathecid spp. 1 and 2 (Figs. 11.11–11.13, 12.14, 12.15).

Possible stem-group aculiferans are conspicuous and include the palaeoloricate *Qaleruaqia sodermanorum* Peel, 2020c (Figs. 13.14–13.19, 15.9–15.11) and the sachitid (halkieriid) *Hippopharangites groenlandicus* new species (Fig. 13.1–13.13). The former is the currently the oldest known palaeoloricate and its description by Peel (2020c) motivated a re-appraisal of early molluscan evolution. Robust cap-shaped shells of *Ocruranus*? *kangerluk* new species (Fig. 15.1–15.8), *Ocruranus*? sp. (Fig. 9.10, 9.13), and *Inughuitoconus borealis* new genus new species (Fig. 7.14–7.18) are interpreted as possible aculiferans, following Vendrasco et al. (2009).

The widely distributed bivalve *Pojetaia runnegari* Jell, 1980 (Fig. 9.14–9.18) is the most common mollusk in GGU sample 315045, with more than 50 specimens. Internal molds

of helcionelloids are not common, but include *Capitoconus artus* Skovsted, 2004 (Fig. 14.7, 14.8), *Davidonia rostrata* (Zhou and Xiao, 1984) (Fig. 14.9), *Davidonia taconica* (Landing and Bartowski, 1996) (Fig. 14.10–14.13), and *Yochelcionella greenlandica* Atkins and Peel, 2004 (Fig. 4.1). The range of *Emargimantus tunuensis* (Peel and Skovsted, 2005) (Fig. 4.5) is extended from North-East Greenland to northern Lauge Koch Land. *Figurina*? *polaris* new species (Fig. 4.7, 4.8), *Anabarella*? *navaranae* new species (Fig. 14.4), and *Stenotheca*? *higginsi* new species (Fig. 14.1–14.3) are new helcionelloids currently only known from North Greenland. Only rare internal molds of the otherwise cosmopolitan *Pelagiella* sp. (Fig. 7.12) are known from Navarana Fjord.

Materials and methods

Carbonate rock samples were digested in weak acetic acid and the dried, sieved residues were picked by hand under a binocular microscope. Selected specimens were gold-coated prior to scanning electron microscopy, using a Zeiss Supra 35VP scanning electron microscope; images were assembled using Adobe Photoshop CS4.

Locality information.—GGU sample 313012 was collected by A.K. Higgins on June 28th 1984 from the lowest beds of the Aftenstjernesø Formation on the southern limb of the prominent Navarana Fjord anticline (Fig. 1.1, locality A; 82°35.5′N, 42°14′W). In this section the Aftenstjernesø Formation attains a thickness of 18 m, culminating in a 3–4 m thick debris flow; overlying strata are assigned to the Henson Gletscher Formation. Fossils from GGU sample 313012 are illustrated in Figure 3. GGU sample 315028 was collected by J.S. Peel on July 3rd 1984 from the same locality, but clearly not the same horizon, as GGU sample 313012; its fossils are illustrated in Figure 4.

GGU sample 315045 was collected by J.S. Peel on July 7th 1984 on the east side of Navarana Fjord on the northern limb of the Navarana Fjord anticline (Fig. 11.1, locality B; 82°36.4′ N, 42°18′W) at an altitude of ~260 m a.s.l. It is derived from ~60 cm above the base of Aftenstjernesø Formation, from a 40 cm thick dark, blue-black weathering, bioclastic dolostone with abundant pyrite, with a heavily weathered (phosphatized?), irregular, upper surface. The underlying stratum yields large tubes of *Hyolithellus* in life position (GGU sample 315043; not figured). Fossils from GGU sample 315045 are illustrated in Figures 5–15.

Preservation.—Following acid treatment, fossils were seen to be preserved typically as phosphatic internal molds (Fig. 9.16), as thin phosphatic coatings (Fig. 11.4), or replacements (Fig. 10) of the now dissolved originally calcareous shells. Exquisite details of echinoderm stereom may be retained (Fig. 8.15, 8.16). Large specimens of the rhynchonelliform brachiopod *Obolella crassa* in GGU sample 315045 are coarsely silicified, but smaller specimens and their internal molds are phosphatized (Fig. 6.2, 6.10), lending support to the notion that the assemblage has been transported down slope. While opercula of hyoliths are abundant in GGU sample 315045 (Fig. 11), accompanying remains of the conchs are rare.

Fragments of poorly preserved, large, phosphatic internal molds of hyoliths (Fig. 4.3) accompany abundant, well-preserved, but much smaller opercula in GGU sample 315028.

A characteristic feature of microfossils from GGU sample 315045 is their encrustation with authigenic euhedral albite crystals (Figs. 5.1, 8.16, 12.5, 13.14), the composition of which was determined by Raman spectroscopy. Although generally strewn across the surfaces, the crystals may be partially embedded in the outer phosphatic coating. Albite encrustation is not currently known from other Greenland localities. Daly (1917) described subhedral albite from dolostones of the Cambrian Waterton Formation of Alberta that he considered to be formed in situ prior to sediment consolidation, as appears to be the case at Navarana Fjord. Hearn and Sutter (1985) reported the widespread development of authigenic potassium feldspar in Cambrian carbonates throughout the Appalachians, an occurrence considered due to the migration of late Paleozoic brines, and similar scenarios were invoked by Harper et al. (1995) and Spötl et al. (1999). In contrast, Álvaro and Bauluz (2008) considered euhedral feldspar crystals in Cambrian limestones from the Moroccan Atlas Mountains to be of pyroclastic origin, but there is no evidence to support such an interpretation in the North Greenland occurrence. At this time. however, the encrusting albite crystals are known only from GGU sample 315045, invalidating the more regional theories concerning the origin of the albite.

Repositories and institutional abbreviations.—GGU prefix indicates a sample collected by Grønlands Geologiske Undersøgelse (Geological Survey of Greenland), now part of the Geological Survey of Denmark and Greenland, Copenhagen, Denmark. Specimen repositories: Natural History Museum of Denmark, Copenhagen (MGUH prefix); Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing, China (NIGPAS prefix); New York State Museum, Albany (NYSM prefix); Museum of Evolution, Uppsala University, Sweden (PMU prefix); South Australian Museum, Adelaide (SAMP prefix); Senckenberg Museum, Frankfurt (SMF prefix).

Systematic paleontology

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Phylum Arthropoda Siebold, 1848
Class Trilobita Walch, 1771
Order Eodiscida Kobayashi, 1939
Superfamily Eodiscoidea Raymond, 1913
Family Weymouthiidae Kobayashi, 1943
Genus *Serrodiscus* Richter and Richter, 1941

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Type species.—*Serrodiscus serratus* Richter and Richter, 1941, lower Cambrian of Spain.

Remarks.—*Serrodiscus* has been described from North Greenland by Peel (1979), Blaker and Peel (1997), and Peel and Willman (2018). The stratigraphically oldest material, *Serrodiscus* sp. 1 of Peel and Willman (2018), occurs in mudstones near the middle of the Buen Formation in southern Peary Land in strata interpreted as straddling the

Montezuman-Dyeran (Cambrian Stage 3-Stage 4) boundary. *Serrodiscus* sp. 2 of Peel and Willman (2018), described by Blaker and Peel (1997) as *Serrodiscus* sp. A, occurs in the upper Buen Formation (Dyeran Stage). Three additional species were described by Blaker and Peel (1997) from northern Nyeboe Land (Fig. 1.3), where *Serrodiscus* may be abundant in dark limestones of the Aftenstjernesø Formation: *Serrodiscus speciosus* (Ford, 1873); *Serrodiscus daedalus* Öpik, 1975; and *Serrodiscus latus*? Rasetti, 1966. All this material is represented by holaspids, whereas currently described specimens from GGU sample 315045 are known only as meraspids. Sundberg et al. (2016) tentatively recognized a basal *Serrodiscus speciosus* Zone in North Greenland, although the boundaries of this were uncertain.

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Serrodiscus sp.
Figure 5.1–5.6

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Occurrence.—Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Description.—Cephalon almost hemispherical in dorsal view with length about two thirds of width. Greatest transverse width occurs at the level of the antero-lateral spines, about three-fifths of the distance from the front margin to the posterior border. Transverse width reduced from these short spines to the genal angles, which also carry short spines.

Glabella tapers forwards with shallowly convex sides and a pointed anterior, decreasing in relief from posterior to anterior. A blunt spine at the elevated posterior may slightly overhang the steep posterior glabellar margin. An obscure furrow may cross the glabellar slightly anterior to the level of the antero-lateral spines. Preglabellar field is narrow and weakly defined, almost occluded by the border furrow approaching the broad axial furrow; a border furrow cusp may separate the strongly inflated genal areas. Shallow border furrow and slightly convex border, comprising about one-tenth of the length of the cephalon, are of uniform width until widening and flattening just anterior of the genal spines. Cephalon ornamented by fine granules that become elongated into short comarginal ridges near the perimeter. Other skeletal elements are not known.

Materials.—PMU 36889–PMU 36891 and two additional cranidia from GGU sample 315045.

Remarks.—Comparison of these meraspids with holaspids of other specimens of *Serrodiscus* described from North Greenland is obviously hindered by great differences in size and anticipated ontogenetic changes. From a stratigraphical point of view, it is most likely that *Serrodiscus* sp. is the meraspid of *S. speciosus* from the Aftenstjernesø Formation of Nyeboe Land (Blaker and Peel, 1997), the holaspids of which lack antero-lateral spines, but *Serrodiscus* sp. lacks the prominent border tubercles illustrated by Blaker and Peel (1997).

Serrodiscus sp. 1 of Peel and Willman (2018) from the middle Buen Formation in southern Peary Land has antero-lateral spines, but differs in the substantial extension of the border in front of the glabellar. Peel and Willman (2018) argued that the

relatively large size (transverse width of 2–3 mm) of the Buen specimens suggested that they were holaspids in contrast to the meraspids from GGU sample 315045, which attain a maximum transverse width of ∼500 μm.

Antero-lateral cephalic spines, as preserved in *Serrodiscus* sp., are also seen in meraspids of *Serrodiscus ctenoa* Rushton, 1966 from the Purley Shale Formation (Cambrian Series 2) of central England, but they are lost in holaspids of *Serrodiscus ctenoa* at a transverse width of 1.5 mm (Rushton, 1966). Similarly, antero-lateral spines are present in meraspids of *Tannudiscus balanus* Rushton, 1966 from the Purley Shale Formation, but absent in its holaspids.

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Family Eodiscidae Raymond, 1913
Genus *Pagetides* Rasetti, 1945

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Type species.—*Pagetides elegans* Rasetti, 1945, from the upper "Anse Miranda Formation" conglomerate at Ville-Guay (late Cambrian Stage 4), Québec.

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Pagetides? sp.
Figure 5.7, 5.8

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Occurrence.—Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Materials.—PMU 36892 from GGU sample 315045.

Remarks.—This single internal mold is similar to a pygidium with attached thoracic segments of *Pagetides elegans* Rasetti, 1945 that were illustrated by Blaker and Peel (1997, fig. 23.1) from the upper Henson Gletscher Formation of Løndal, south-western Peary Land. It differs in the axis of the pygidium having fewer axials rings and terminating at a greater distance from the posterior margin. Prominent axial nodes are present on all segments, with the most-anterior ones curved towards the posterior and more transversely elongate. Pleural surfaces pass smoothly onto the border without the development of border furrows.

Pagetides elegans is abundant in the southern Freuchen Land-Peary Land area in an *Ovatoryctocara granulata* assemblage (Cambrian Series 2, latest Stage 4), the *Bonnia-Pagetides elegans* Zone of Sundberg et al. (2016), in the upper Henson Gletscher Formation (Geyer and Peel, 2011), and in the correlated upper "Anse Miranda Formation" conglomerate at Ville-Guay (Landing et al., 2002). The pair of faint pleural ridges crossing the pleural areas on each segment in the Navarana Fjord specimen are reminiscent of the pygidium of *Yukonides lacrinus* Fritz, 1972 from the Sekwi Formation (Cambrian Stage 3) of the Mackenzie Mountains (Fritz, 1972, pl. 8, fig. 12; see also Fritz 1973, pl. 3, fig. 32), but the Greenland specimen has a narrower axis and broad pleural furrows.

<div align="center">

Family Yukoniidae Zhang in Zhang et al., 1980
Genus *Ekwipagetia* Fritz, 1973

</div>

Type species.—*Ekwipagetia plicofimbria* Fritz, 1973 from Cambrian Series 2 (Stage 3), Mackenzie Mountains, north-western Canada.

Ekwipagetia sp.
Figure 5.9, 5.10

Occurrence.—Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Materials.—PMU 36893 from GGU sample 315045.

Remarks.—The axial and pleural furrows in this single broken pygidium are broader and less sharply defined than in material from the Kap Troedsson Formation (Cambrian Stage 4) in southern Wulff Land (Fig. 1.3) assigned to *Ekwipagetia marginata* (Rasetti, 1967) by Blaker and Peel (1997). The surface is covered with fine tubercles. The prominent axial spine is located more anteriorly than in pygidia of *Ekwipagetia plicofimbria* illustrated by Fritz (1973), which are also more inflated. Skovsted (2006a) illustrated a heavily coated specimen from the upper Bastion Formation (Cambrian Stage 4) of North-East Greenland as *Ekwipagetia*, but it is too poorly preserved to compare with the material from North Greenland.

Class uncertain
Order Bradoriida Raymond, 1935
Family Mongolitubulidae Topper et al., 2007
Genus *Spinospitella* Skovsted, Brock, and Paterson, 2006

Type species.—*Spinospitella coronata* Skovsted, Brock, and Paterson, 2006 from the Mernmerna Formation of South Australia, Cambrian Series 2, Stage 4.

Remarks.—Skovsted et al. (2006a) described *Spinospitella* from the Mernmerna Formation (Cambrian Stage 3–4) of South Australia based on broken, but relatively complete, bradoriid carapaces. Spines and plate-like fragments are covered by numerous smaller, second order, spines, which themselves are encircled by crowns of minute third order spines.

Spinospitella coronata Skovsted, Brock, and Paterson, 2006
Figure 3

2006 *Spinospitella coronata* Skovsted, Brock, and Paterson, p. 21, figs. 6–9.
2007 *Spinospitella coronata*; Topper et al., p. 85, fig. 9.
2016 *Spinospitella coronata*; Betts et al., fig. 20L–P.

Holotype.—SAMP 41425, Mernmerna Formation of 'Angorichina' Station, Flinders Ranges, South Australia (Skovsted et al., 2006, fig. 9A–C).

Occurrence.—Mernmerna Formation of South Australia, Holyoake Formation of East Antarctica (Claybourn et al., 2019), Aftenstjernesø Formation and probably Buen Formation of North Greenland; Cambrian Series 2, Stage 4.

Materials.—PMU 36980 from GGU sample 313012.

Remarks.—*Spinospitella coronata* was fully described by Skovsted et al. (2006), who placed particular emphasis on the nature of the spinose ornamentation. An almost complete shield from northern Lauge Koch Land (Fig. 3) displays fine details of the outer surface ornamentation that are obscured by a thin, crystalline or flaky, diagenetic phosphatic coating. However, the diagnostic circlets of third order spines (Fig. 3.4) are visible on the second order spines covering the surface of the shield. The single specimen is slightly crushed: length ∼3.4 mm (Fig. 3.1), height about half of length. The holotype (Skovsted et al., 2006, fig. 9A) is only half as high, while specimens figured by Topper et al. (2007) have a maximum length of 2.1 mm. The great size difference between the specimen from northern Lauge Koch Land and the complete juvenile, length 750 μm, figured by Skovsted et al. (2006, fig. 9D–F) is accompanied by ontogenetic changes in morphology, particularly the enhanced postplete shape and greater prominence of the antero-dorsal spine. The first order spines increase in prominence in the adult and their tips turn in towards each other (Fig. 3.6). Second order spines are strongly developed and more acute.

Assemblages of small carbonaceous fossils described by Slater et al. (2018) and Wallet et al. (2020) from the middle Buen Formation of southern Peary Land contain numerous fragments of *Spinospitella*.

Phylum Cnidaria Hatschek, 1888
Genus Olivooides Qian, 1977

Type species.—*Olivooides multisulcatus* Qian, 1977 from the early Cambrian (Meishucunian Stage) of China.

Olivooides? sp.
Figure 5.15

Occurrence.—Aftenstjernesø Formation of North Greenland, Cambrian Series 2, Stage 4.

Materials.—PMU 36897 from GGU sample 315045.

Remarks.—This single spherical fossil has a diameter of almost 400 μm. Its surface is encrusted by a diagenetic granular layer of phosphate that preserves the imprints of numerous crystal termini and in which micaceous flakes are embedded. Similar phosphatized spheres of varying size, with a smooth envelope, are often interpreted as egg capsules. Their later ontogenetic development is well known in the case of material referred to *Olivooides* Qian, 1977, to which the current specimen is tentatively referred, and *Markuelia* Valkov, 1983. Phosphatized spheres are known from the Ediacaran (Xiao et al., 2014; Cunningham et al., 2017; Anderson et al., 2019) and Cambrian and Early Ordovician (Donoghue et al., 2006) in Canada, China, Siberia, Australia, and USA. Specimens from the Yukon Territory referred to *Olivooides* by Pyle et al. (2006) are up to more than 1 mm in diameter. *Olivooides* is generally regarded as a cnidarian (Dong et al., 2016), while *Markuelia* is interpreted as a scalidophoran (Dong et al., 2010). The affinities of Ediacaran forms are obscure (Cunningham et al., 2017).

Phylum Brachiopoda Duméril, 1806
Subphylum Linguliformea Williams et al., 1996
Class Lingulata Gorjansky and Popov, 1985
Order Lingulida Waagen, 1885
Superfamily Linguloidea Menke, 1828
Family Eoobolidae Holmer, Popov, and Wrona, 1996
Genus *Eoobolus* Matthew, 1902

Type species.—*Obolus* (*Eoobolus*) *triparilis* Matthew, 1902 from Cambrian Series 3 of Cape Breton Island, Canada.

Eoobolus priscus (Poulsen, 1932)
Figure 5.11, 5.12

1932 *Lingulella* (*Lingulepis*) *prisca* Poulsen, p. 13, pl. 1, figs 1–5.
2005 *Eoobolus priscus*; Skovsted and Holmer, p. 330, pl. 2, figs. 1–13; pl. 3, figs. 1–11 (see for earlier synonymy).
2007 *Eoobolus priscus*; Skovsted and Peel, fig. 2a, b.
2007 *Eoobolus priscus*; Paterson et al., p. 138, fig. 3a–e.
2010 *Eoobolus priscus*; Skovsted and Peel, fig. 2.22.
2017 *Eoobolus priscus*; Skovsted et al., p. 28, fig. 15.

Holotype.—MGUH 3503, upper Bastion Formation, Hyolithus Creek, Kap Weber, North-East Greenland (Poulsen, 1932, pl. 2, fig. 1).

Occurrence.—See Skovsted et al. (2017), and subsequently Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Materials.—PMU 36894 and PMU 36895 from GGU sample 315045, and fragments from GGU sample 315028.

Remarks.—The illustrated internal surface of the dorsal valve (Fig. 5.11) agrees with material described from the Bastion Formation of North-East Greenland (Skovsted and Holmer, 2005). Skovsted et al. (2017) noted that *Eoobolus priscus* was characteristic of outer shelf deposits in the Forteau Formation, whereas *Botsfordia caelata* (Walcott, 1912) occurred in higher energy, transgressive, inner shelf deposits. Rare specimens of each occur together in GGU sample 315045 from Navarana Fjord.

Superfamily Acrotheloidea Walcott and Schuchert in Walcott, 1908
Family Botsfordiidae Schindewolf, 1955
Genus *Botsfordia* Matthew, 1891

Type species.—*Obolus pulcher* Matthew, 1889 from the Cambrian of New Brunswick.

Botsfordia sp.
Figure 5.13, 5.14

Occurrence.—Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

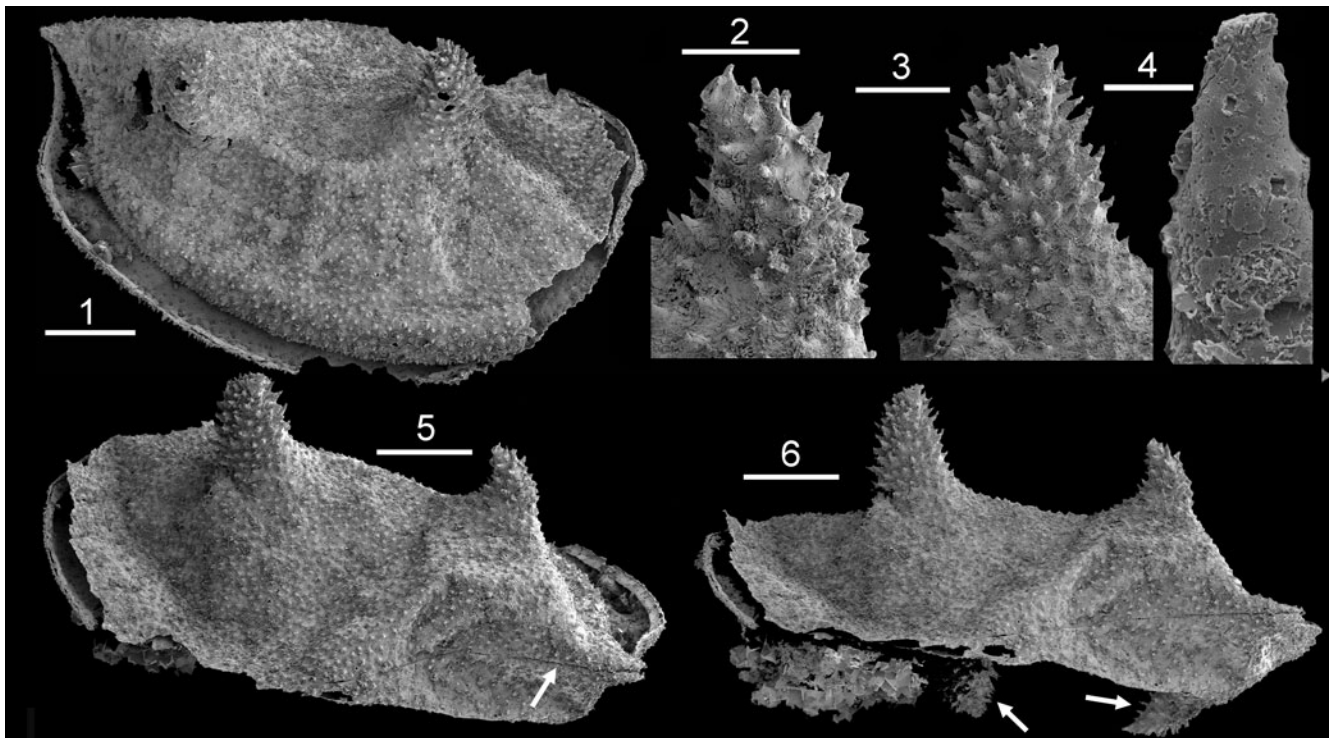*Materials.*—A single fragment, PMU 36896 from GGU sample 315045.

Figure 3. *Spinospitella coronata* Skovsted, Brock, and Paterson, 2006, PMU 36980 from GGU sample 313012, Aftenstjernesø Formation, Navarana Fjord, Cambrian Series 2, Stage 4. (**1**) Left valve in lateral view; (**2**) anterior first order spine with covering of second order spines; (**3**) posterior first order spine with covering of second order spines; (**4**) second order spine with corona of third order spines; (**5**) dorso-lateral view showing hinge line (arrow); (**6**) dorsal view showing spines on right valve (arrowed), anterior to right. Scale bars: 10 μm (**4**), 100 μm (**2, 3**), 500 μm (**1, 5, 6**). SEM images: Christian B. Skovsted.
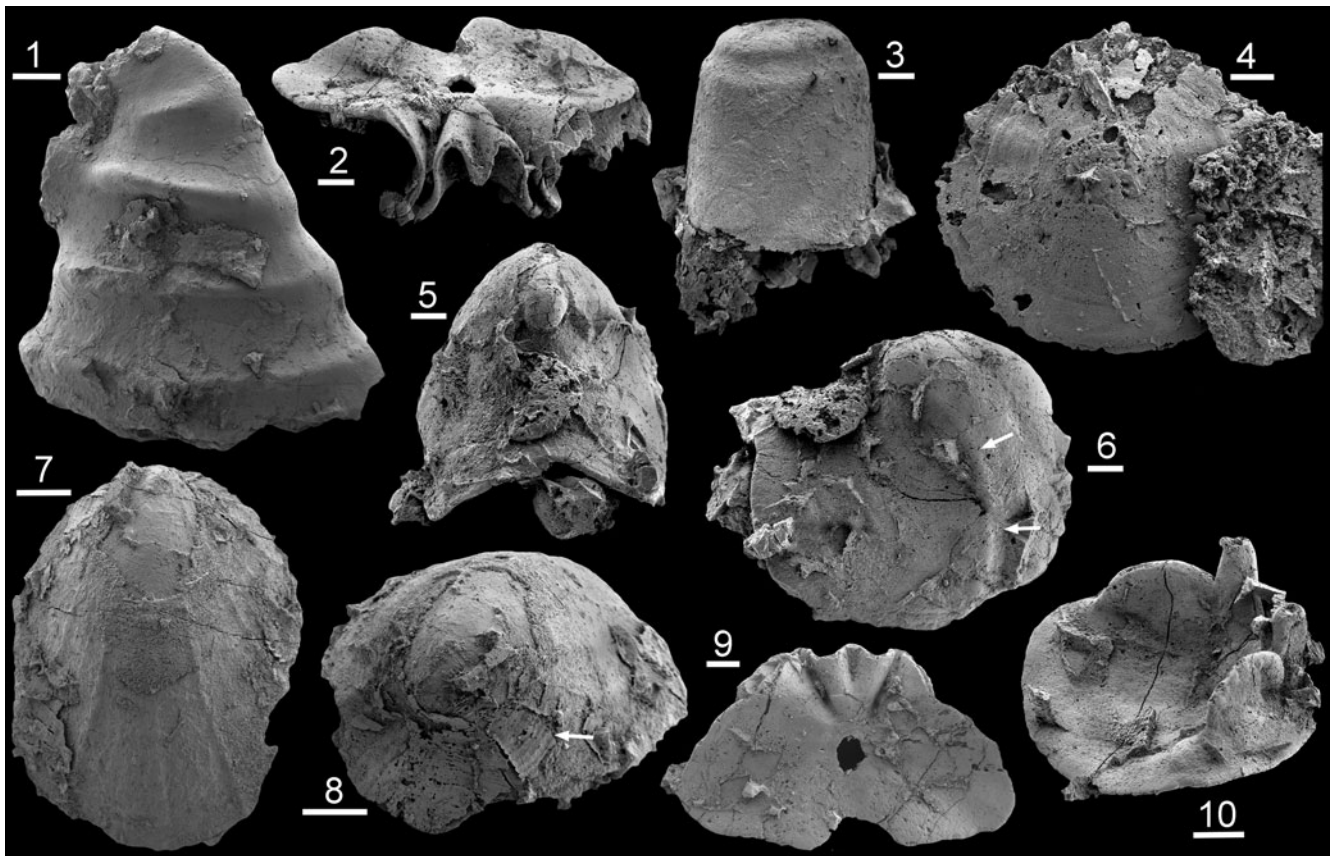
Figure 4. Helcionelloids and hyoliths from GGU sample 315028, Aftenstjernesø Formation, Navarana Fjord, Cambrian Series 2, Stage 4. (**1**) *Yochelcionella greenlandica* Atkins and Peel, 2004, PMU 36882, lateral view of internal mold with broken apex; (**2, 9**) *Triplicatella sinuosa* Skovsted, Peel, and Atkins, 2004, PMU 36883, hyolith operculum showing folded dorsal margin (**2**) and plan view of external surface (**9**); (**3**) *Cupitheca* sp., PMU 36884, hyolith internal mold; (**4**) *Hyptiotheca*? sp., PMU 36885, operculum external surface; (**5, 6**) *Emargimantus tunuensis* (Peel and Skovsted, 2005), PMU 36886, encrusted internal mold showing sub-apical surface (**5**) and in dorso-lateral view (**6**) with radial carina arrowed; (**7, 8**) *Figurina*? *polaris* n. sp., PMU 36887, holotype, in dorsal (**7**) and sub-apical (**8**) views; (**10**) *Conotheca*? sp. 2, PMU 36888, oblique lateral view of operculum inner surface. Scale bars: 200 μm (**1, 3, 7, 8**), all others 100 μm.

Remarks.—*Botsfordia* Matthew, 1891 is represented only by a single fragment, but this shows the characteristic initial growth stage of the dorsal valve (Fig. 5.13, 5.14). The fragment likely belongs to *Botsfordia caelata* (Walcott, 1912), which in North Greenland (Fig. 1.3) may be abundant in samples from the Kap Troedsson Formation in southern Wulff Land (Peel, 2014a), and was also described from the Wulff River Formation of Inglefield Land by Poulsen (1927). *Botsfordia* is known also from the uppermost Buen Formation at Navarana Fjord (Peel and Willman, 2018), while Skovsted and Holmer (2005) described material from the Bastion Formation of North-East Greenland (Fig. 1.2). Skovsted et al. (2017) gave a full synonymy while describing material from the Forteau Formation of Labrador and Newfoundland, with Ushatinskaya and Korovnikov (2016) reviewing records from Siberia and elsewhere. All these occurrences are from Cambrian Stage 4.

Subphylum Rhynchonelliformea Williams et al., 1996
Class Obolellata Williams et al., 1996
Order Obolellida Rowell, 1965
Superfamily Obolelloidea Walcott and Schuchert in Walcott, 1908
Family Obolellidae Walcott and Schuchert in Walcott, 1908
Genus *Obolella* Billings, 1861

Type species.—*Obolella chromatica* Billings, 1861 from Cambrian Series 2, Anse au Loup, Canada.

Obolella crassa (Hall, 1847)
Figure 6

1847 *Orbicula*? *crassa* Hall, p. 290, pl. 79, fig. 8a.
1912 *Obolella crassa*; Walcott, p. 592, pl. 54, fig. 2a–n, text fig. 14.
1932 *Obolella congesta* Poulsen, p. 14, pl. 1, figs 6–13.
1962 *Obolella crassa*; Rowell, p. 137.
2005 *Obolella crassa*; Skovsted and Holmer, p. 340, pl. 5, figs. 1–15.
2007 *Obolella crassa*; Skovsted and Peel, fig. 2H, I.

Holotype.—Not designated (see Walcott, 1912, p. 851).

Occurrence.—See Skovsted and Holmer (2005) and subsequently the Forteau Formation of western Newfoundland and the Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Description.—Biconvex, slightly longer than wide, and acuminate at the posterior (Fig. 6.1–6.4) in the small
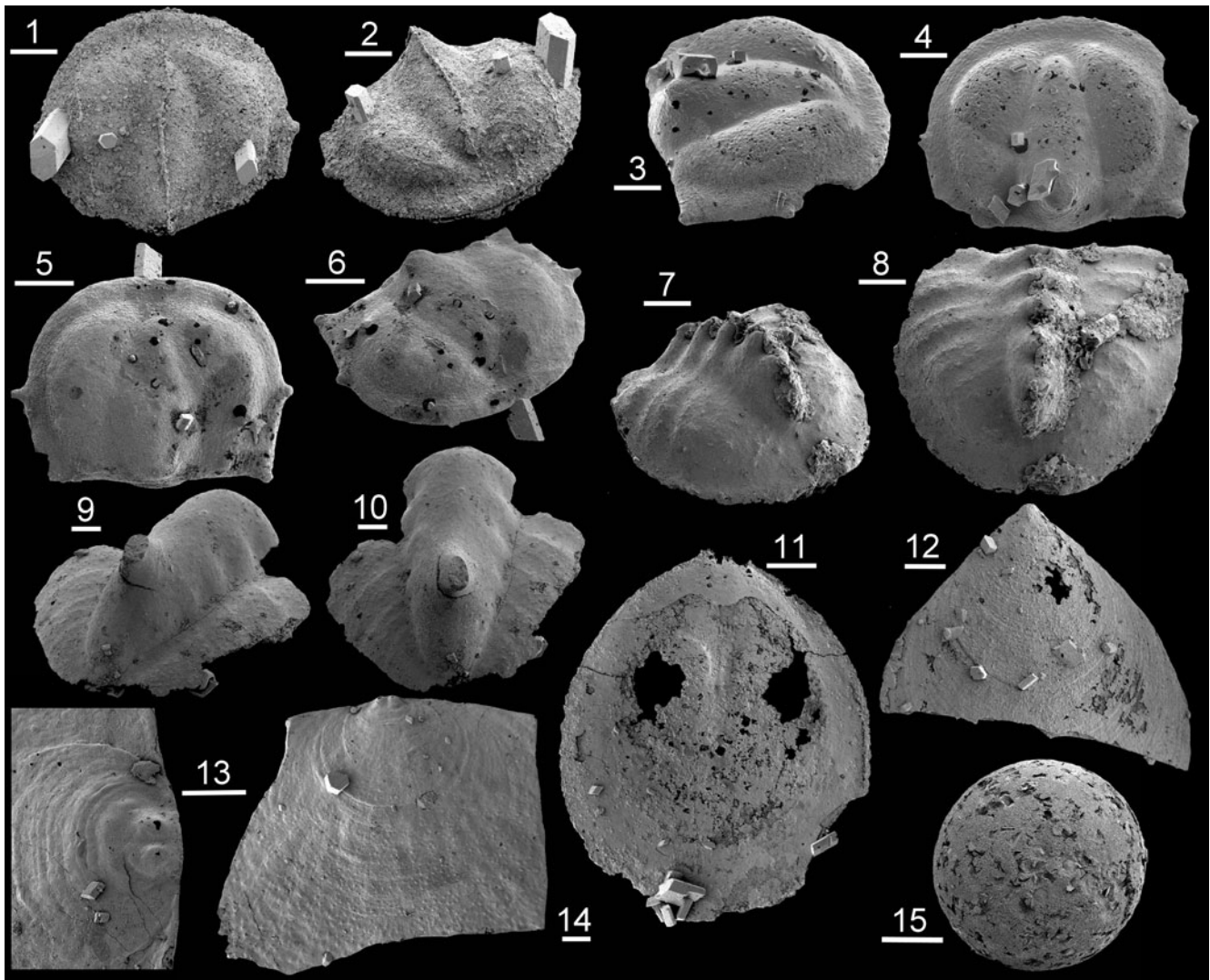
Figure 5. Trilobites, brachiopods, and a cnidarian from GGU sample 315045, Aftenstjernesø Formation, Navarana Fjord, Cambrian Series 2, Stage 4. (**1–6**) *Serrodiscus* sp., cranidia; (**1, 2**) PMU 36889; (**3, 4**) 36890; (**5, 6**) PMU 36891; (**7, 8**) *Pagetides*? sp., PMU 36892, pygidium with attached thoracic segments; (**9, 10**) *Ekwipagetia* sp., PMU 36893, fragment of pygidium; (**11, 12**) *Eoobolus priscus* (Poulsen, 1932); (**11**) PMU 36894, ventral valve; (**12**) PMU 36895, dorsal valve, interior; (**13, 14**) *Botsfordia* sp., PMU 36896, dorsal valve, with detail of first-formed shell (**13**); (**15**) *Olivooides*? sp., 36897, encrusted with diagenetic mineralization. Scale bars: 200 μm (**12**), all others 100 μm.

specimens illustrated here. External surfaces appear to be slightly worn with only periodic comarginal growth lamellae retained to form a step-wise profile near the anterior margin (Fig. 6.4).

Viewed internally, the prominent triangular pseudointerarea of the ventral valve is bisected by a deep and narrow pedicle groove (Fig. 6.1, 6.5) built up of imbricate lamellae (Fig. 6.5). Anterior margin of the pseudointerarea curves convexly forward on either side of the pedicle groove, forming lateral concavities in the pseudointerarea margin that reflect the position of the posterior margin of the posterior adductor muscles (Fig. 6.5, pm); resultant deep cavities are often evident even in less well-preserved material (Fig. 6.2, arrows). Sides of the pedicle groove formed by struts supporting the pseudointerarea; groove circular in cross-section, with overhanging margins, and seemingly tubular in form in some specimens (Fig. 6.10). Visceral platform raised, forming a depressed ring on the internal mold (Fig. 6.10). Form of muscle attachment scars and vasculae not known, apart from the posteriormost adductor pair (Fig. 6.5, pm).

Internal molds of dorsal valve with transversely elongate posterior muscle scars adjacent to notothyrium (Fig. 6.6, 6.7) and medial depression corresponding to a raised oval visceral platform on the shell interior (Fig. 6.7). Visceral platform about half of length of preserved specimens (Fig. 6.7, 6.8), with sharp median ridge (groove on internal mold) lying centrally within a broad, shallow median hollow (raised on internal mold; Fig. 6.7–6.9). U-shaped anterior adductor scar symmetrically disposed around anterior end of the median (Fig. 6.7, 6.9).

Valve interior with widely spaced small pits preserved as fine tubercles on internal mold (Fig. 6.7, 6.9).

Materials.—PMU 36898–PMU 36904 and ~15 additional isolated valves from GGU sample 315045.

Remarks.—*Obolella crassa* was fully described by Skovsted and Holmer (2005) from the upper Bastion Formation of North-East Greenland, with *Obolella congesta* Poulsen, 1932 from the same area placed in synonymy. *Obolella crassa* is the only common brachiopod in the samples from Navarana Fjord. The most common specimens attain a length of 5.5 mm and are coarsely silicified, with attached small crystals and patches of pyrite. Rare small specimens illustrated herein attain a length of ~600 µm (Fig. 6) and are generally phosphatized. They are encrusted with scattered euhedral crystals of albite, as is the case with other fossils of similar size in the acid residue. Differences from material illustrated by Skovsted and Holmer (2005), including the slightly acuminate shape (Fig. 6.1–6.4), probably reflect the larger size of their North-East Greenland material. Specimens figured by Poulsen (1932) exceed 10 mm in diameter (Skovsted and Holmer, 2005, pl. 5, fig. 1), ~20 times larger than most specimens figured here (Fig. 6).

The median forward curvature of the anterior margin of the pseudointerarea in the ventral valve and the deep pits associated with the posterior adductor muscles (Fig. 6.1, 6.2, 6.5) resemble the closely related *Bicia* Walcott, 1912, as illustrated by Rowell (1962) and Ushatinskaya (1988).

Phylum Porifera Grant, 1836
"Stem Calcarea + Homoscleromorpha" sensu Botting and Muir, 2018
Genus *Eiffelia* Walcott, 1920

Type species.—*Eiffelia globosa* Walcott, 1920 from the Burgess Shale (Miaolingian) of British Columbia.

Eiffelia sp.
Figure 7.1

Occurrence.—Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Materials.—PMU 36905 from GGU sample 315045.

Remarks.—Peel (2019a) reported robust spicules of the calcarean *Eiffelia* from the Aftenstjernesø and Kap Troedsson formations at several localities in North Greenland. Single specimens of six-rayed (Fig. 7.1) and four-rayed forms are known from GGU sample 315045.

Class Hexactinellida Schmidt, 1870

slender hexactine
Figure 7.11

Occurrence.—Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Materials.—PMU 34334 from GGU sample 315045.

Remarks.—Botting and Muir (2018) considered that the widely used name *Calcihexactina* Sdzuy, 1969 for spicules of this type

lacked any useful meaning, and Peel (2019a) recommended that it should be restricted to the type suite.

Common hexactins and rare pentactins from GGU sample 315045 are characterized by long, slender rays of uniform diameter and with a circular cross-section (Fig. 7.11). In the context of North Greenland spicule assemblages, these distinctive spicules were reported by Peel (2019a) from several localities within the Kap Troedsson and Aftenstjernesø formations in North Greenland. The four paratangential rays may lie within a single plane perpendicular to the axial ray, but they are often inclined, or slightly curved, towards it.

Similar spicules were illustrated from the Bastion Formation in North-East Greenland by Skovsted (2006a), and from Cambrian Series 2 in the United Kingdom (Brasier, 1984; Hinz, 1987), China (Ding and Qian, 1988; Mao et al., 2013), and Antarctica (Wrona, 2004). Rays in specimens from the lower-middle Cambrian of Korea referred to *Calcihexactina* by Lee (2006) are more robust and more strongly tapering. Specimens assigned to *Calcihexactina* by Brock and Cooper (1993) from the early Cambrian of South Australia also have more tapered rays than the Greenland spicules, with less sharply defined junctions between the rays. Kouchinsky et al. (2015) illustrated slender pentactins from the Emyaksin Formation (Cambrian Series 2, Stages 2–3) of northern Siberia, but these differ from the North Greenland specimens in that the paratangential rays slope away from the axial ray rather than shallowly towards it.

"Protomonaxonida" sensu Botting and Muir, 2018
Order Chancelloriida Walcott, 1920
Family Chancelloriidae Walcott, 1920
Genus *Chancelloria* Walcott, 1920

Type species.—*Chancelloria eros* Walcott, 1920 from Cambrian (Miaolingian) of British Columbia, Canada.

Chancelloria sp.
Figure 7.2–7.4, 7.8

Occurrence.—Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Materials.—PMU 36906 and PMU 36907 from GGU sample 315045.

Remarks.—Most of the ~20 fragmentary sclerites of *Chancelloria* have ray formulas of 8 + 1 (8 radial rays and one perpendicular axial ray) to 10 + 1 (Fig. 7.2–7.4, 7.8). Radial rays are usually curved slightly towards the axial ray and most are similar in length; the axial ray is usually longer and more robust. The overall sclerite form is similar to *Platyspinatus digitatus* Vassiljeva, 1985 from the Terreneuvian of Yakutia, Siberia (Vassiljeva, 1985), but similar sclerites were also illustrated by Kouchinsky et al. (2011) from Cambrian Series 3 in northern Siberia. Too few sclerites are available to assess meaningfully spicule composition in the scleritome.
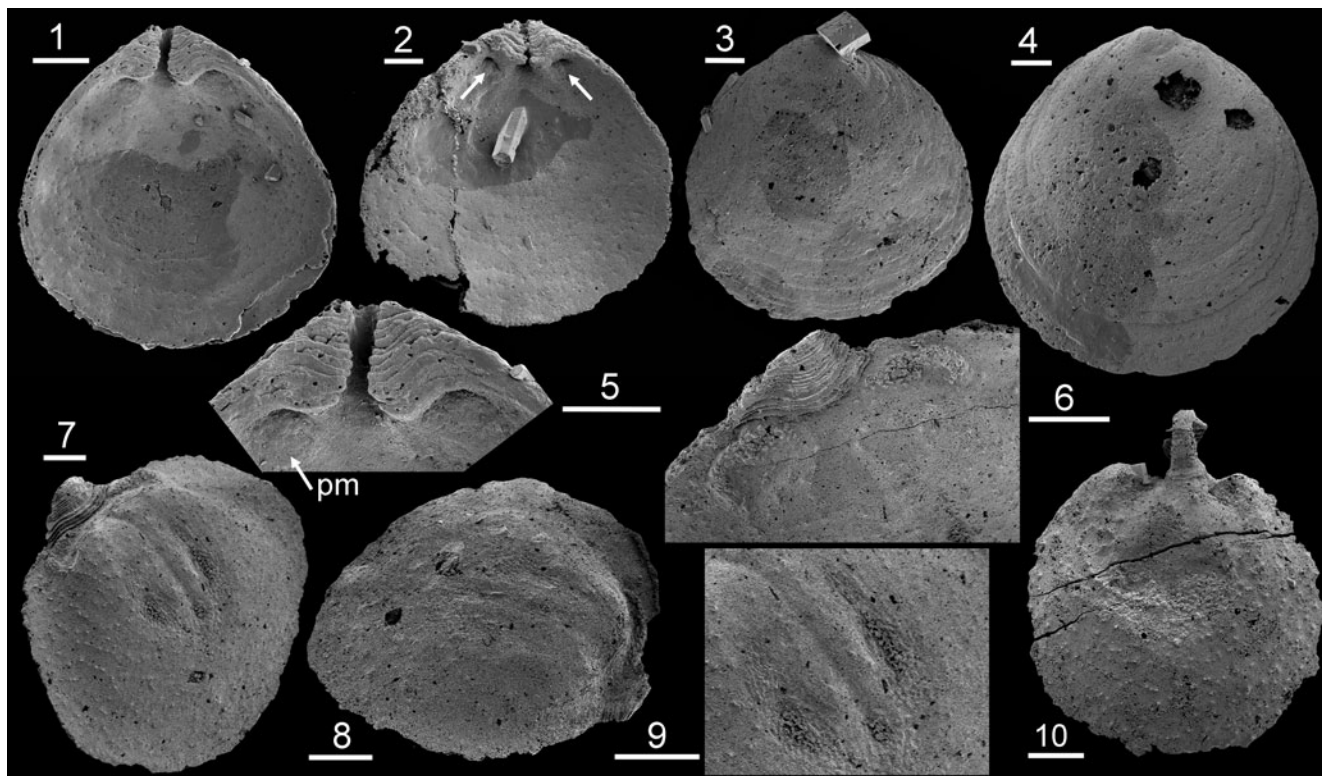
Genus *Archiasterella* Sdzuy, 1969

Figure 6. *Obolella crassa* (Hall, 1847) from GGU sample 315045, Aftenstjernesø Formation, Navarana Fjord, Cambrian Series 2, Stage 4. (**1, 5**) PMU 36898, internal surface of ventral valve showing detail of pseudointerarea (**5**) with posterior adductor muscle scar (pm); (**2**) PMU 36899, internal surface of ventral valve showing lateral depressions in front of pseudointerarea (arrows); (**3**) PMU 36900, dorsal valve exterior; (**4**) PMU 36901, ventral valve exterior; (**6, 7, 9**) PMU 36902, internal mold of dorsal valve, with detail of scars of posterior adductor muscles (**6**) and anterior adductor muscles around median groove (**9**); (**8**) PMU 36903, internal mold of dorsal valve with anterior adductor muscle scars; (**10**) PMU 36904, internal mold of ventral valve with visceral area and rod-like infilling of pedicle groove/tube. Scale bars = 100 μm.

Type species.—*Archiasterella pentactina* Sdzuy, 1969 from Sierra Morena, Spain, Cambrian.

Remarks.—An emended diagnosis was presented by Moore et al. (2014). An axial ray is lacking, but one of the radial rays is strongly bent perpendicular to the plane of the remaining rays.

Archiasterella cf. *A. pentactina* Sdzuy, 1969
Figure 7.5–7.7, 7.9

Holotype.—SMF 26167, Molinos Shale, Cazalla de la Sierra, Sierra Morena, southern Spain (Sdzuy, 1969, pl. 15, fig. 12).

Occurrence.—See Moore et al. (2014) and (Devaere et al., 2019), subsequently Aftenstjernesø Formation, Navarana Fjord, Cambrian Series 2, Stage 4.

Materials.—PMU 36908–PMU 36910 and ~20 additional sclerites from GGU sample 315045.

Remarks.—In describing material from the Shiyantou Formation of Yunnan, China (Terreneuvian Series), Moore et al. (2014) gave a full synonymy and revision of *Archiasterella*. Sclerites illustrated as *Archiasterella* cf. *pentactina* by Moore et al. (2014) show greater inflation of the axial parts of the rays than specimens from GGU sample 315045 or those figured by Sdzuy (1969). Devaere et al. (2019) presented an extensive discussion

of three-, four-, and five-rayed species of *Archiasterella* from the Puerto Blanco Formation (Cambrian Stages 2–4) of Mexico, recognizing their utility in the establishment of four assemblages of small shelly fossils. Most of the sclerites from GGU sample 315045 are five-rayed forms (Fig. 7.7, 7.9) that resemble specimens assigned to *Archiasterella* cf. *A. pentactina* by Devaere et al. (2019). They occur together with rare three-rayed (Fig. 7.5) and four-rayed (Fig. 7.6) sclerites, which likely belong to the same scleritome, although individually referred to *Allonia erromenosa* (Jiang in Luo et al., 1982) and *Allonia tetrahallis* (Jiang in Luo et al., 1982) by Devaere et al. (2019).

?Phylum Chaetognatha Leuckart, 1854
Class, Order, and Family Uncertain
Genus *Hertzina* Müller, 1959

Type species.—*Hertzina americana* Müller, 1959 from the Cambrian of Nevada.

Hertzina? sp.
Figure 7.10, 7.13

Occurrence.—Aftenstjernesø Formation of North Greenland, Cambrian Series 2, Stage 4.

Materials.—PMU 36911, a single specimen from GGU sample 315045.

Remarks.—The concave sub-apical surface and lateral angulations invite comparison with *Hertzina* Müller, 1959, in which the supra-apical surface is uniformly rounded in the type species *H. americana* Müller, 1959. However, specimens of *H. elongata* Müller, 1959 from the Furongian of Sweden illustrated by Müller and Hinz (1991, fig. 9) may have an acutely angled supra-apical surface. In terms of the medial flange on the supra-apical surface, this specimen resembles *Hagionella cultrata* Missarzhevsky, 1977, but the flange in the latter is much more prominent (Peel et al., 2016). Additionally, the transverse profile of the sub-apical surface is uniformly convex in *Hagionella cultrata* whereas it is concave in *Hertzina*? sp.

Landing and Bartowski (1996, fig. 9.14, 9.15) illustrated, but did not describe, two specimens assigned to *Hertzina elongata* from the Browns Pond Formation (Cambrian Series 2, Stage 4) of the Taconic sequence in New York in which the sub-apical surface is closely similar to the current specimen.

<div align="center">

Phylum Echinodermata Klein, 1754
Edrioasteroid thecal plates
Figure 8.1, 8.5, 8.8, 8.10–8.12, 8.14, 8.15

</div>

Materials.—PMU 36915–PMU 36919 from GGU sample 315045.

Remarks.—Similar plates in a similar state of preservation were described from the upper Emyaksin Formation of the Anabar Uplift in Siberia (Cambrian Series 2, Botoman Stage, *Calodiscus-Erbiella* Biozone) by Kouchinsky et al. (2015).

<div align="center">

Edrioasteroid ambulacral flooring plates?
Figure 8.6, 8.9

</div>

Materials.—PMU 36920 and PMU 36921 from GGU sample 315045.

Remarks.—These two figured plates are tentatively interpreted as edrioasteroid ambulacral flooring plates after comparison with specimens illustrated by Clausen and Peel (2012) from the Henson Gletscher Formation (Cambrian Miaolingian Series, Wuliuan Stage) of Peary Land, North Greenland.

<div align="center">

Echinoderm thecal plates
Figure 8.2–8.4, 8.7, 8.13, 8.16

</div>

Materials.—PMU 36922–PMU 36926 from GGU sample 315045.

Remarks.—Most of the plates placed here exhibit a prominent honeycomb pattern on the outer surface (Fig. 8.2–8.4) that is reminiscent of the pattern seen on co-occurring edrioasteroid thecal plates (Fig. 8.8, 8.11), suggesting a common derivation. A similar pattern was illustrated in plates from the Browns Pond Formation of New York State (Landing and Bartowski, 1996). Plates with and without epispires are present. A rectangular, pyramidal plate with radiating ridges on one side (Fig. 8.7, 8.13) may be a brachioliferous plate.

<div align="center">

"Hyolitha"
Phylum uncertain

</div>

Remarks.—As chronicled by Malinky and Yochelson (2007), hyoliths have been regarded as a class of mollusks (Class Hyolitha Marek, 1963) or a separate phylum. Moysiuk et al. (2017) considered them to be lophophorates, but Liu et al. (2019) considered it more likely that they are basal lophotrochozoans. Hyoliths are traditionally subdivided into two orders, Hyolitha and Orthothecida (but see Kruse, 2002). Peel and Yochelson (1984) proposed Toxeumorphorida Shimansky, 1962 as a third order of hyoliths for a group of Permian conical shells earlier regarded as part of the defunct Class Xenoconchia (Shimanksy, 1963; Starobogatov, 1974).

<div align="center">

Order Hyolithida Syssoiev, 1957
Family uncertain
Genus *Microcornus* Mambetov, 1972

</div>

Type species.—*Microcornus parvulus* Mambetov, 1972, lower Cambrian of Kazakhstan.

<div align="center">

Microcornus? sp.
Figure 15.12

</div>

Occurrence.—Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Materials.—PMU 36880 from GGU sample 315045.

Remarks.—This single, partially exfoliated fragment of a conch has a low, arched dorsum and a flattened ventral surface. Ornamentation consists of growth lamella that curve slightly towards the aperture just prior to passing around the angular lateral edges of the conch. The median dorsal plane of a similar conch from the Bastion Formation of North-East Greenland described by Malinky and Skovsted (2004, fig. 3A, B) has a prominent angulation on the shell exterior that is only weakly discernible in the internal mold from North Greenland. *Microcornus* is globally distributed in Cambrian stages 3–5 (Pan et al., 2019).

<div align="center">

Genus *Parkula* Bengtson in Bengtson et al., 1990

</div>

Type species.—*Parkula bounites* Bengtson in Bengtson et al., 1990 from the Parara Limestone (Cambrian Series 2) of South Australia.

<div align="center">

Parkula bounites Bengtson in Bengtson et al., 1990
Figure 9.4–9.8, 9.12

</div>

1990 *Parkula bounites* Bengtson in Bengtson et al., p. 223, figs. 149–151.
2004 *Parkula bounites*; Malinky and Skovsted, p. 559, figs. 3g, 4a, b.
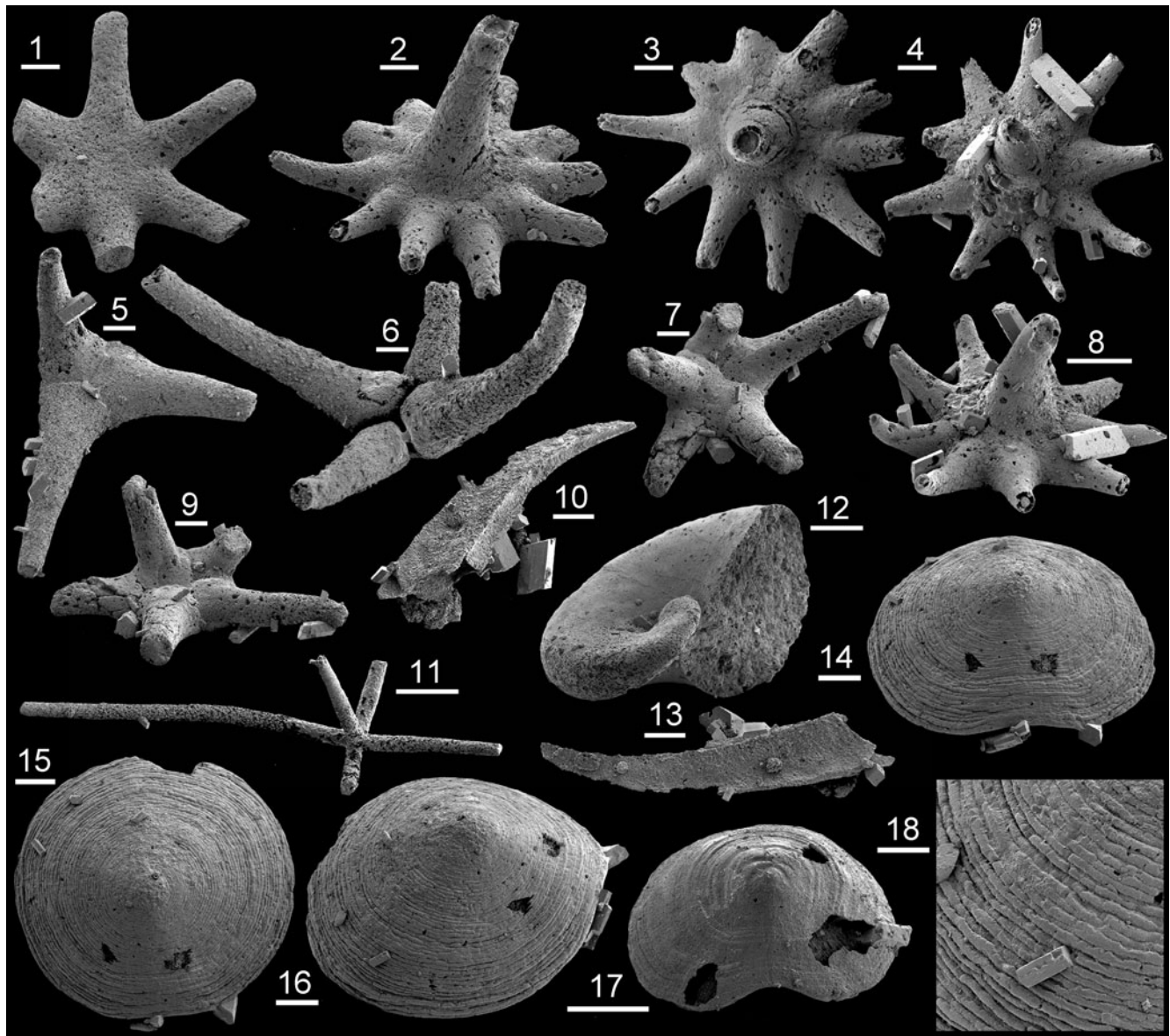2019 *Parkula bounites*; Devaere et al., p. 33, fig. 15.7–15.20.

Figure 7. Small shelly fossils GGU sample 315045, Aftenstjernesø Formation, Navarana Fjord, Cambrian Series 2, Stage 4. (**1**) *Eiffelia* sp., PMU 36905; (**2–4, 8**) *Chancelloria* sp., (**2, 3**) PMU 36906; (**4, 8**) PMU 36907; (**5–7, 9**) *Archiasterella* cf. *A. pentactina* Sdzuy, 1969; (**5**) PMU 36908, three-rayed form; (**6**) PMU 36909, four-rayed form; (**7, 9**) PMU 36910, five-rayed form; (**10, 13**) *Hertzina*? sp., PMU 36911; (**11**) slender hexactine, PMU 34334; (**12**) *Pelagiella* sp., PMU 36912; (**14–18**) *Inughuitoconus borealis* n. gen. n. sp.; (**14–16, 18**) PMU 36913, holotype, in oblique dorsal (**14**), dorsal (**15**), and dorso-lateral (**16**) views, with detail of ornamentation (**18**); (**17**) PMU 36914, paratype, oblique view of sub-apical surface. Scale bars: 200 μm (**5, 6, 8, 13, 14**), all others 100 μm.

Holotype.—SAMP 30892, Parara Limestone, Kulpara, South Australia (Bengtson et al., 1990, fig. 149A–C).

Occurrence.—See Devaere et al. (2019) and subsequently Aftenstjernesø Formation of North Greenland, Cambrian Series 2, Stages 3–4.

Materials.—PMU 36928–PMU 36931 from GGU sample 315045.

Remarks.—The specimens from North Greenland differ from the slightly older type material from South Australia in having a more pointed dorsal margin to the cardinal area (Fig. 9.6, 9.12) and less-protruding cardinal processes. With regard to shape, they are similar to specimens described by Malinky and Skovsted (2004) from the Bastion Formation of North-East Greenland and by Skovsted and Peel (2007) from the Forteau Formation of western Newfoundland.

Parkula esmeraldina Skovsted, 2006b, from the Emigrant Formation (Cambrian Stage 4, Dyeran) of Nevada, is distinguished by having prominent comarginal growth ornamentation on the conical shield and robust cardinal processes that project strongly into the conch interior. These strong cardinal processes are also seen in *Parkula* cf. *P. esmeraldina* of Kouchinsky et al. (2015) from the upper Emyaksin Formation (Botoman Stage) of Siberia and were compared by Pan et al. (2019) to *Protomicrocornus* Pan et al., 2019 from the early Cambrian of the North China Platform.

The well-defined circular summit (Fig. 9.12) was also illustrated by Devaere et al. (2019, fig. 15.13, 15.19) from the Puerto Blanco Formation of Sonora, Mexico, and by Pan et al. (2019) in material from North China, although the cardinal processes are more prominent in the latter material.

Genus *Cassitella* Malinky and Skovsted, 2004

Type species.—*Cassitella baculata* Malinky and Skovsted, 2004 from the Bastion Formation, Cambrian Series 2, Stage 4, of North-East Greenland.

Cassitella baculata Malinky and Skovsted, 2004
Figure 10

2004   *Cassitella baculata* Malinky and Skovsted, p. 574, fig. 15.
2007   *Cassitella baculata*; Skovsted and Peel, p. 741, fig. 5m, n.

Holotype.—MGUH 27130 from GGU sample 314835, upper Bastion Formation, Albert Heim Bjerge, North-East Greenland (Malinky and Skovsted, 2004, fig. 15a).

Occurrence.—Upper Bastion Formation, North-East Greenland, Forteau Formation, western Newfoundland and Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Materials.—PMU 36937–PMU 36942 from GGU sample 315045; a single specimen from GGU sample 315028.

Remarks.—*Cassitella baculata* Malinky and Skovsted, 2004 was proposed on the basis of material from the Bastion Formation (Cambrian Stage 4) of North-East Greenland by Malinky and Skovsted (2004) who also noted its occurrence in the Aftenstjernesø Formation of southern Peary Land, North Greenland and the Forteau Formation of western Newfoundland. Specimens from the Bastion Formation are of similar size to the Aftenstjernesø Formation examples, but the latter are taller, with more steeply inclined lateral areas. The distinctive raised, circular, earliest growth stage illustrated by Malinky and Skovsted (2004, fig. 15 $C_{3, \, 4}$) has not been observed.

Cassitella baculata has a robust thick shell and is similar in this respect to the contemporaneous *Ocruranus*? *kangerluk* n. sp. (Fig. 15.1–15.8). The external surface is circular to slightly angular at the dorsal margin with the summit located at about one-third of the distance from the dorsal margin to the ventral edge. It is divided into a short concave cardinal surface and a long convex conical shield, but without the distinct groove or fold that is present in most hyolithids. The massive internal processes are two in number, rounded at their dorsal extremity (Fig. 10.2), but becoming blade-like towards the ventral surface (Fig. 10.9), possibly suggesting incipient division into cardinal processes and clavicles. The processes extend beyond the plane of the aperture (Fig. 10.7, 10.8, 10.10) and their edges may show division into minor lobes (Fig. 10.11).

In lateral view (Fig. 10.8, 10.11), the curvature of the margin suggests that the operculum belonged to a hyolithid conch with an amblygonal aperture and well-developed ligula; there is no indication of folds for the passage of helens. Unlike most hyolithids, the cardinal surface slopes downward rather than upward towards the dorsal margin, indicating that the operculum summit was raised above the dorsum of the conch, as suggested also by the arched sub-apical margin (Fig. 10.4).

Massive thickening of the internal processes is also present in *Protomicrocornus* from the early Cambrian of the North China Platform (Pan et al., 2019, fig. 8), where the summit is located similarly close to the dorsal margin, but bounded by an upturned ridge partly equivalent to the narrow cardinal shield. Pan et al. (2019) noted that various specimens referred to *Parkula* Bengtson in Bengtson et al., 1990 by Malinky and Skovsted (2004), Skovsted (2006b), and Kouchinsky et al. (2015) resembled *Protomicrocornus* in this respect, and *Cassitella* may be related to this group. It differs, however, in the manner in which the dorsal surface in *Parkula* is strongly turned back towards the summit of the operculum, such that inner surface with the cardinalia is projected forward (Skovsted, 2006b, fig. 3e, f). This upturned dorsal margin is not seen in *Cassitella baculata* Malinky and Skovsted, 2004, but it is present in specimens from the Bastion Formation of North-East Greenland referred to *Cassitella* sp. by Skovsted (2006a, fig. 10.24–10.27).

Genus *Hyptiotheca* Bengtson in Bengtson et al., 1990

Type species.—*Hyptiotheca karraculum* Bengtson in Bengtson et al., 1990 from the Parara Limestone of South Australia.

Hyptiotheca? sp.
Figure 4.4

Occurrence.—Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Materials.—PMU 36885 from GGU sample 315028.

Remarks.—This single specimen shows broad folds (rooflets) that extend radially from the summit towards the margins, separating the dorsal (cardinal) and ventral (conical) shields of the outer surface. The outer surface is shallowly convex and the summit lies closer to the presumed dorsal margin. Characters of the inner surface are not known. Similar radial folds are known in *Hyptiotheca karraculum* Bengtson et al., 1990 described from the Parara Limestone (Bengtson et al., 1990) and from the Bastion Formation of North-East Greenland (Malinky and Skovsted, 2004). Such folds are also present in *Nasaaraqia hyptiotheciformis* Peel and Willman, 2018, described from the Buen Formation (Cambrian Stage 4) in southern Peary Land, which is distinguished by a third fold, which bisects the cardinal shield. Ornamentation consists of fine comarginal growth lines (Peel and Willman, 2018).

Order Orthothecida Marek, 1966
Family Circotothecidae Missarzhevsky, 1969
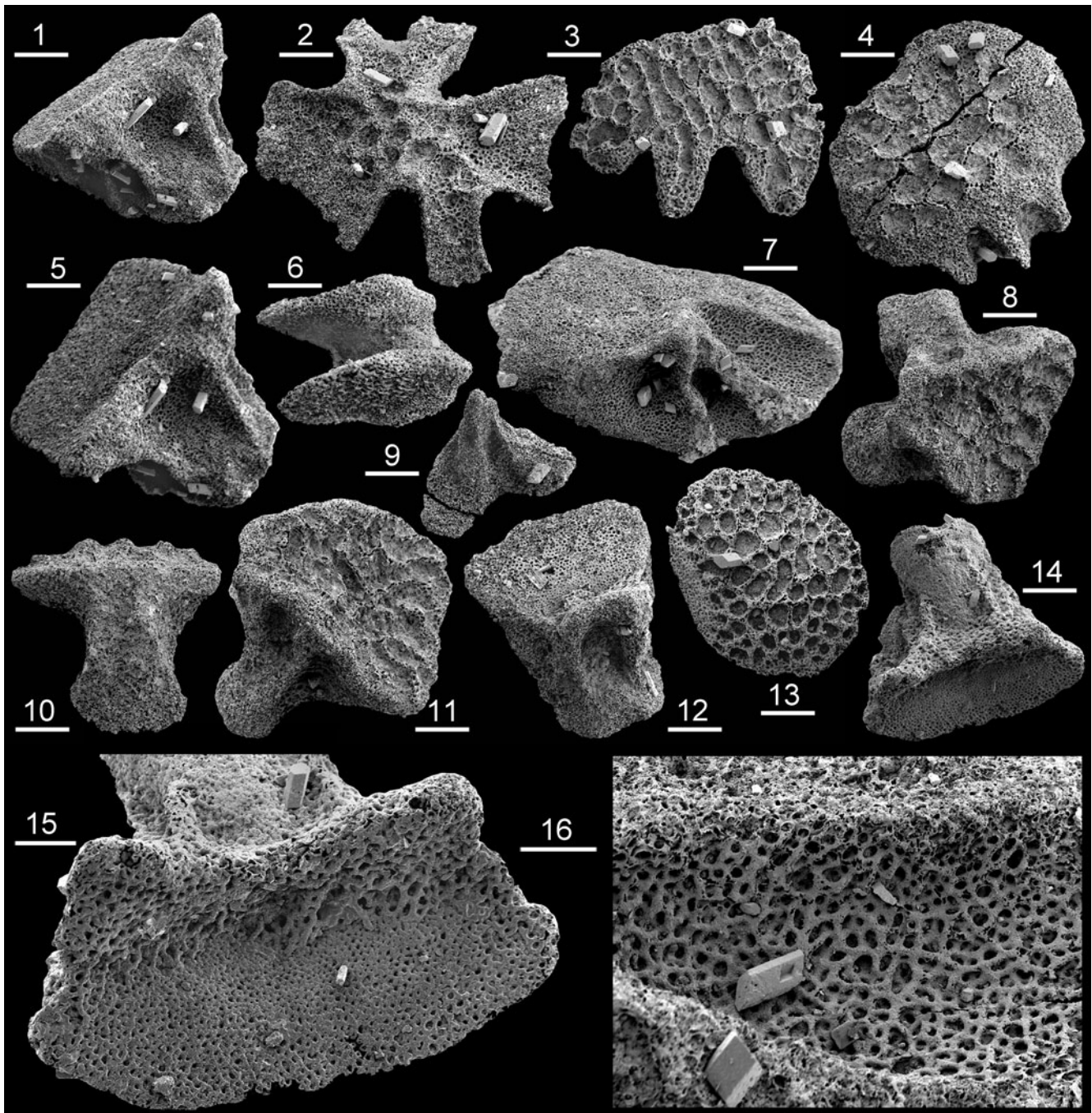Genus *Conotheca* Missarzhevsky, 1969

Figure 8.   Echinoderm plates from GGU sample 315045, Aftenstjernesø Formation, Navarana Fjord, Cambrian Series 2, Stage 4. (**1, 5, 8, 10–12, 14, 15**) Edrioasteroid thecal plates; (**1, 5**) PMU 36915; (**8, 11**) PMU 36916; (**10**) PMU 36917; (**12**) PMU 36918; (**14, 15**) PMU 36919, with detail of stereom (**15**); (**6, 9**) edrioasteroid ambulacral flooring plates? (**6**) PMU 36920; (**9**) PMU 36921; (**2–4, 7, 13, 16**) echinoderm thecal plates; (**2**) PMU 36922; (**3**) PMU36923; (**4**) PMU 36924; (**7, 16**) PMU 36925, with detail of stereom; (**13**) PMU 36926. Scale bars: 100 μm (**15, 16**), all others 200 μm.

Type species.—Conotheca mammilata Missarzhevsky, 1969, Cambrian, Tommotian Stage, Siberian Platform.

Conotheca laurentiensis Landing and Bartowski, 1996
Figures 11.18–11.20, 12.12, 12.13

1996   *Conotheca laurentiensis* Landing and Bartowski, p. 756, fig. 7.3, 7.4, 7.6.

2004   *Conotheca australiensis* Bengtson in Bengtson et al.; Malinky and Skovsted, p. 572, fig. 14.

Holotype.—NYSM 15558, Browns Pond Formation, New York State, Cambrian Series 2, Stage 4.

Occurrence.—New York State, Québec, and North Greenland, Cambrian Series 2, Stage 4.

Materials.—PMU 36952 and PMU 36959 from GGU sample 315045.

Remarks.—Only opercula of *Conotheca laurentiensis* Landing and Bartowski, 1996 are known from Navarana Fjord. The external surface is shallowly convex, almost flat, with concentric growth lines. A slightly raised initial growth stage is located at about one-third of the distance from the dorsal margin to the ventral margin (Fig. 11.18, arrow). On the inner side, a clavicular ring is raised along the ventro-lateral portions into radially striated clavicular ridges (Fig. 12.12). The cardinal processes are sub-circular in cross-section. Unlike the prominent horizontal clavicular spines of *Neogloborilus* sp., the cardinal processes in the latter are much longer and more robust than in *Conotheca laurentiensis*.

Malinky and Skovsted (2004) and Pan et al. (2019) considered *Conotheca laurentiensis* to be a junior synonym of *Conotheca australiensis* Bengtson in Bengtson et al., 1990 from the Parara Limestone of South Australia, but Landing and Bartowski (1996) stressed the shorter cardinal processes and radiating tubules of the latter. Specimens from the Bastion Formation of North-East Greenland illustrated by Malinky and Skovsted (2004, fig. 14) are conspecific with the Navarana Fjord material.

Conotheca? sp. 1
Figure 11.3–11.8, 11.14–11.16

2004 *Operculum* sp. B Malinky and Skovsted, p. 562, fig. 7.

Occurrence.—Aftenstjernesø Formation, North Greenland, and the upper Bastion Formation North-East Greenland; Cambrian Series 2, Stage 4.

Materials.—PMU 36944–PMU 36948 from GGU sample 315045.

Remarks.—*Conotheca*? sp. 1 is known only from opercula (diameter ~1.2 mm) with a flat outer surface with concentric growth rings. The inner surface is divided into an outward sloping border zone and a concave center by a clavicular ring. Long, slender, cardinal processes located close to the dorsal margin are circular in cross-section (Fig. 11.5–11.7). The clavicules diverge from the median line, slightly overhanging the clavicular ring laterally (Fig. 11.5, 11.15). They are blade-like, longer than wide, and may show a tendency towards division into two.

Operculum B of Malinky and Skovsted (2004, fig. 7) from the Bastion Formation of North-East Greenland is assigned to *Conotheca*? sp. 1. The operculum of *Conotheca hensoni* Peel et al., 2016, from the Henson Gletscher Formation of southern Peary Land, is distinguished from *Conotheca*? sp. 1 in having has two short clavicular teeth located ventrally, within the clavicular ring of each of its cardinal processes, whereas a single prominent clavicule is present in *Conotheca*? sp. 2.

Conotheca sp. of Kouchinsky et al. (2015, fig. 28A, B) from the Emyaksin Formation of Siberia differs from *Conotheca*? sp. 1 in lacking clavicules. In *Conotheca rotunda* Qian, Yin, and Xiao, 2000 from the Yuertus Formation (Cambrian Series 2) of Xinjiang, China, the clavicular ring is composed

of a series of short rods, and prominent clavicles of the type seen in *Conotheca*? sp. 1 are absent.

Conotheca? sp. 2
Figure 4.10

Occurrence.—Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Materials.—PMU 36888, GGU sample 315028.

Remarks.—*Conotheca*? sp. 2 differs from *Conotheca*? sp. 1 in lacking a clavicular ring joining the ventral terminations of the clavicles. Additionally, the blade-like clavicles are convex in lateral profile (Fig. 4.10), while those of *Conotheca*? sp. 1 are prongs.

Genus *Neogloborilus* Qian and Zhang, 1983

Type species.—*Neogloborilus applanatus* Qian and Zhang, 1983, Cambrian Series 2, Qiongzhusian Stage, South China.

Neogloborilus sp.
Figures 9.1–9.3, 11.1, 11.2

Occurrence.—Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Materials.—PMU 36927 and PMU 36943 from GGU sample 315045.

Remarks.—This species is known in northern Lauge Koch Land only from the large operculum (diameter ~1.2 mm), which has a concave outer surface with concentric growth rings. The inner surface is convex, without a clavicular ring. A pair of large cardinal processes is located close to the dorsal margin; they are blade-like near their bases, but become circular in cross-section distally (Fig. 9.2) and are raised prominently above the inner surface of the operculum. A cylindrical, horizontal clavicule is directed ventrally from the base of each cardinal process. The clavicules diverge slightly towards the ventral margin of the operculum and are extended into spines at their ventral end (Fig. 9.1, 9.3). The clavicles in *Neogloborilus applanatus* Qian and Zhang, 1983, as illustrated by Pan et al. (2019) from the Xinji Formation (Cambrian Series 2) of North China, are shorter and not distally spinose.

Pan et al. (2019) noted the similarity of Operculum B of Malinky and Skovsted (2004, fig. 7) from the Bastion Formation of North-East Greenland with *Neogloborilus*, although herein it is compared to *Conotheca*? sp. 1. Operculum A of Skovsted and Peel (2007, fig. 5H) from the Forteau Formation of western Newfoundland is closely similar to *Neogloborilus* sp., but its cardinal processes diverge in a V-shape, whereas those of the Greenland form have a wider, U-shaped relationship (Fig. 9.3).

Neogloborilus sp. differs from *Conotheca hensoni* from the Henson Gletscher Formation (Cambrian Stage 4) of southern Peary Land in terms of its deep concave outer surface and lack of a clavicular ring on the inner surface (Peel et al., 2016). In
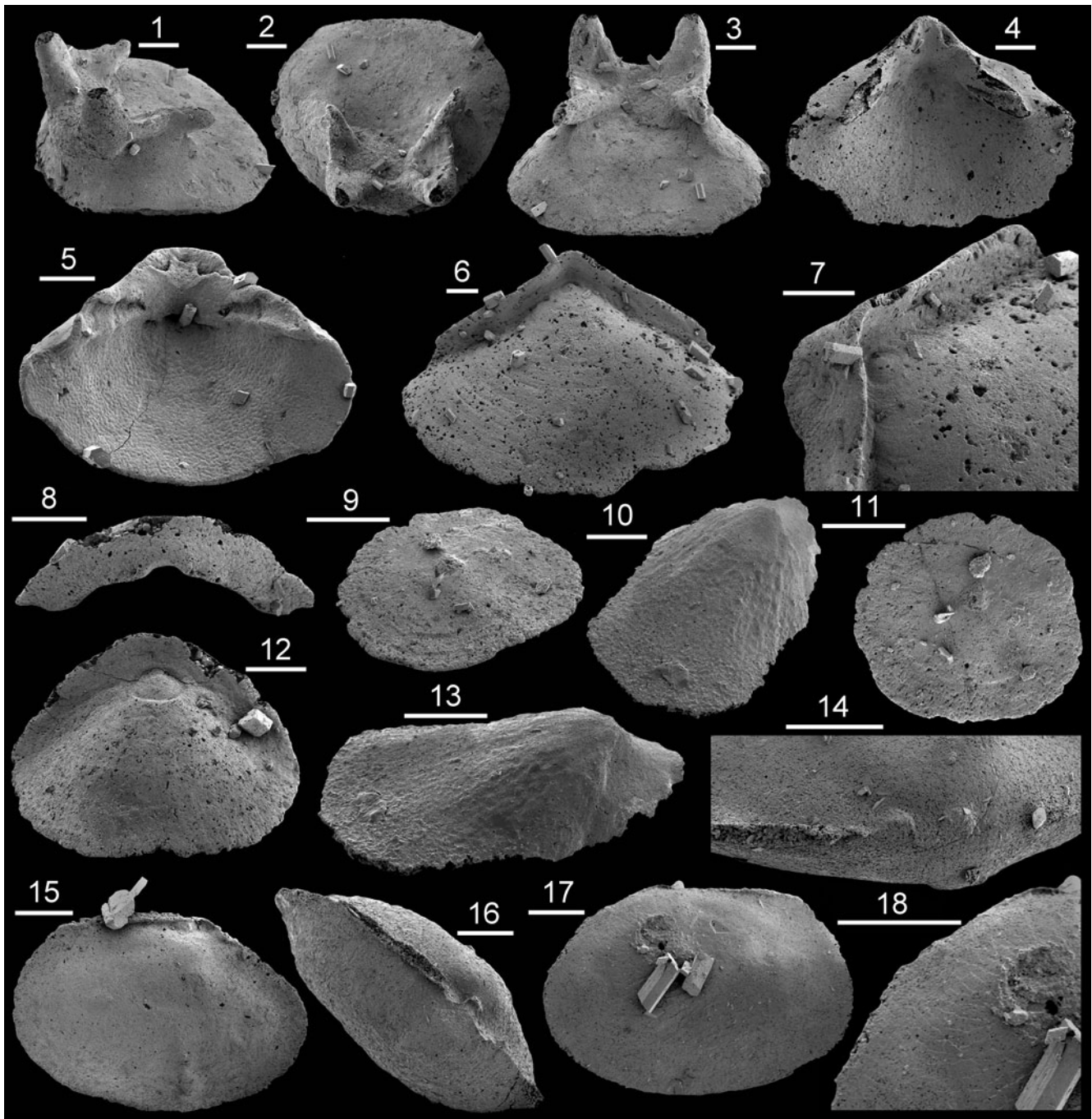
Figure 9. Hyolith opercula and mollusks from GGU sample 315045, Aftenstjernesø Formation, Navarana Fjord, Cambrian Series 2, Stage 4. (**1–3**) *Neogloborilus* sp., PMU 36927, oblique (**1, 3**) and plan (**2**) views of inner surface of operculum; (**4–8, 12**) *Parkula bounites* Bengtson in Bengtson et al., 1990, opercula; (**4**) PMU 36928, internal surface; (**5**) 36929, internal surface; (**6, 7**) PMU 36930, external surface showing circular early growth stage at summit (**7**); (**8, 12**) PMU 36931, internal surface of cardinal area (**8**) and external view (**12**); (**9, 11**) operculum sp. 2; PMU 36932, external views; (**10, 13**) *Ocruranus*? sp., PMU 36933, oblique dorsal views of internal mold; (**14–18**) *Pojetaia runnegari* Jell, 1980; (**14, 16**) PMU 36934, detail of dentition (**14**) and umbonal view of internal mold (**16**); (**15**) PMU 36935, right lateral view; (**17, 18**) PMU 36936, left lateral view (**17**) with impression of shell structure (**18**). Scale bars = 200 μm.

addition, *Conotheca hensoni* has two short clavicular teeth located ventrally from its cylindrical cardinal processes, whereas *Neogloborilus* sp. has a single, large, horizontally directed clavicular tooth on each side. The external surface of opercula of *Conotheca laurentiensis* differs from *Neogloborilus* sp. in being almost flat (Fig. 11.18–11.20). On the inner side of *Conotheca laurentiensis*, a well-developed clavicular ring is elevated into latero-ventral clavicular ridges, unlike the prominent horizontal clavicular spines of *Neogloborilus* sp. The cardinal processes in the latter are longer and more robust than in *Conotheca laurentiensis*.

Family Allathecidae Missarzhevsky, 1969
Allathecid sp. 1
Figure 11.11–11.13, 11.17

Occurrence.—Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Materials.—PMU 36950 and PMU 36951 from GGU sample 315045; two specimens from GGU sample 315028.

Remarks.—The conch is not known. The outer surface of the oval operculum is gently convex with a central summit. Comarginal growth lines are lamellose near the periphery and crossed by obscure fine growth lines (Fig. 11.11). The inner surface has a well-developed clavicular ring that slightly overhangs the deep groove on its distal margin. Internally, the sides of the ring are radially ridged, uneven, and slope towards the center of the operculum. The clavicular walls are robust and of variable height, although markedly higher laterally (Fig. 11.17).

The operculum is similar to specimens from the late Tommotian of Siberia illustrated as *Majatheca tumefacta* Missarzhevsky, 1969 by Kouchinsky et al. (2015, fig. 24) and as *Allatheca* sp., from the late Tommotian of Siberia by Missarezhevsky (1969, pl. XI, fig. 4).

<div align="center">

Allathecid sp. 2

Figure 12.14, 12.15

</div>

Occurrence.—Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Materials.—PMU 36960 from GGU sample 315045; a single specimen from GGU sample 315028.

Remarks.—This operculum has a conical form with a central summit. It is weakly sub-triangular, narrowing dorsally, and is ornamented with coarse radial cords and comarginal growth lines. Internally, the clavicular ring is similar to that of allathecid sp. 1, from which it is distinguished by its prominent radial ornamentation and greater height (Fig. 12.14, 12.15).

<div align="center">

Family uncertain

Genus *Cupitheca* Duan in Xing et al., 1984

</div>

Type species.—*Paragloborilus mirus* He in Qian, 1977 from the lower Cambrian of South China.

<div align="center">

Cupitheca sp.

Figure 4.3

</div>

Occurrence.—Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Materials.—PMU 36884 and one additional specimen from GGU sample 315028.

Remarks.—The internal mold of the characteristic decollated conch resembles that of *Cuptitheca holocyclata* (Bengtson in Bengtson et al., 1990) from the Parara Limestone of South Australia, but information concerning external sculpture is lacking. Similar specimens are widely distributed, including the Bastion Formation of North-East Greenland (Malinky and Skovsted, 2004) and in undescribed collections from the Aftenstjernesø Formation elsewhere in North Greenland. The association of an operculum with a conch of *Cuptitheca holocyclata* was recently described by Skovsted et al. (2016) from the Ajax Formation of South Australia and the Xinji Formation of North China.

<div align="center">

Genus *Triplicatella* Conway Morris in Bengtson et al., 1990

</div>

Type species.—*Triplicatella disdoma* Conway Morris in Bengtson et al., 1990 from the lower Cambrian of South Australia.

Remarks.—Although originally described just on the basis of isolated opercula, articulated complete conchs and opercula of the type species *Triplicatella disdoma* Conway Morris in Bengtson et al., 1990 were described from Cambrian Series 2 in South Australia by Skovsted et al. (2014). Demidenko (2001, pl. X, fig. 7) previously illustrated an operculum and a portion of the conch, also from South Australia. Subsequently, Liu et al. (2019) described articulated *Triplicatella* from the Chengjiang Lagerstätte (Cambrian Stage 3) of China.

<div align="center">

Triplicatella disdoma Conway Morris in Bengtson et al., 1990

Figure 12.1, 12.2, 12.6, 12.7, 12.9, 12.11

</div>

1990 *Triplicatella disdoma* Conway Morris in Bengtson et al., p. 232, figs. 157, 158.
2014 *Triplicatella disdoma*; Skovsted et al., p. 148, figs. 2–4.
2019 *Triplicatella disdoma*; Pan et al., fig. 6F, G.

Holotype.—SAMP 30910, Parara Limestone, Curramulka, South Australia (Bengtson et al., 1990, fig. 157D–F).

Occurrence.—South Australia, North China (Pan et al., 2019) and subsequently Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Materials.—PMU 36953–PMU 36956 from GGU sample 315045.

Remarks.—The prominent transverse bar lying dorsally on the internal surface in the cardinal area of *Triplicatella disdoma* (Fig. 12.2, 12.7) is also present in *Triplicatella peltata* Skovsted, Peel, and Atkins, 2004 described from the Aftenstjernesø Formation of southern Peary Land, the upper Bastion Formation of North-East Greenland, and the Forteau Formation of western Newfoundland (Skovsted et al., 2004). It is less strongly developed in the type material of *Triplicatella disdoma* from South Australia where an angulation is typically developed on the internal surface between the dorsal margin and the center of the operculum (Bengtson et al., 1990, fig. 158E–G). Greenland specimens are variable in shape, from triangular (Fig. 12.1) to oval (Fig. 12.6). A quadrangular form (Fig. 12.3, 12.4) is compared to *Triplicatella xinjia* Pan et al., 2019 from North China, which also has the prominent transverse bar on the internal surface near the dorsum. Folding of the dorsal surface also varies in expression, from prominent (Fig. 12.1) to effaced (Fig. 12.6), the latter specimens resembling *Triplicatella peltata*, as illustrated by Skovsted et al. (2004).
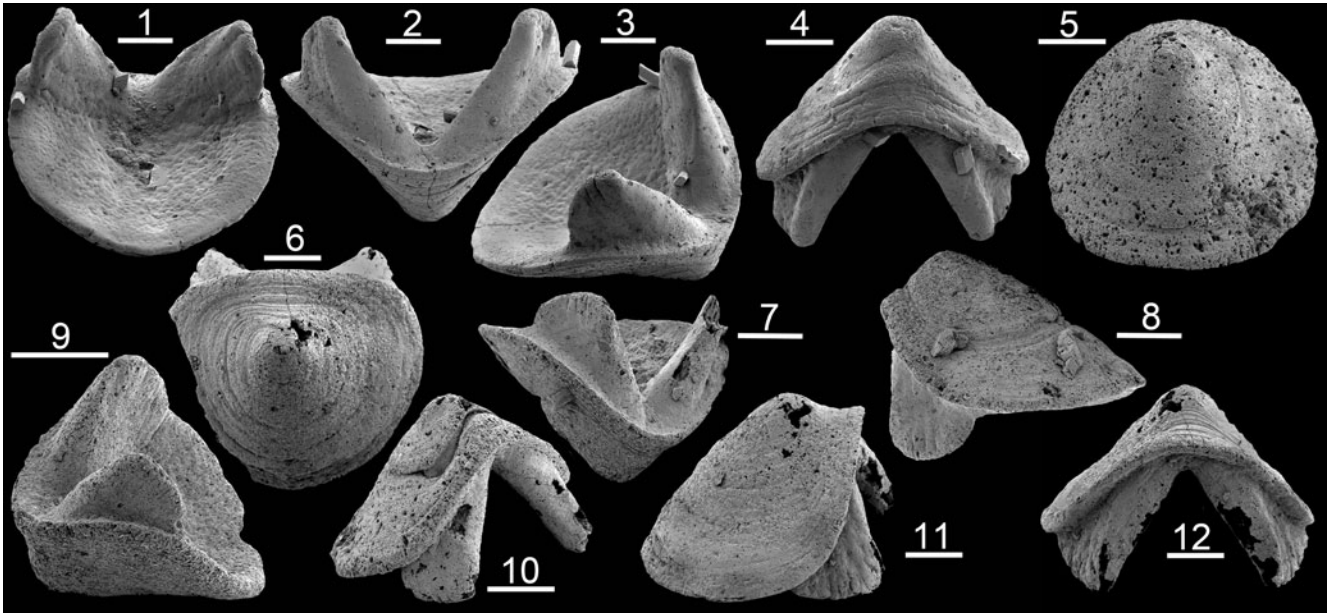
Figure 10. *Cassitella baculata* Malinky and Skovsted, 2004 from GGU sample 315045, Aftenstjernesø Formation, Navarana Fjord, Cambrian Series 2, Stage 4. (**1–3**) PMU 36937, internal views; (**4**) PMU 36938, cardinal surface; (**5, 10**) PMU 36939, external surface (**5**) and oblique view showing growth discontinuity (**10**); (**6, 11, 12**) PMU 36940; (**7, 8**) PMU 36941; (**9**) PMU 36942. Scale bars = 200 μm.

Triplicatella sinuosa Skovsted, Peel, and Atkins, 2004
Figures 4.2, 4.9, 12.5, 12.8, 12.10

2004   *Triplicatella sinuosa* Skovsted, Peel, and Atkins, p. 1279, figs. 2A–K, 3A–F.

Holotype.—MGUH 27064 from GGU sample 314835, upper Bastion Formation, Albert Heim Bjerge, North-East Greenland (Skovsted et al., 2004, fig. 2A, B).

Occurrence.—Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Materials.—PMU 36883 and two additional specimens from GGU sample 315028 (Fig. 4.2, 4.9). PMU 36957 and 36958 from GGU sample 315045 (Fig. 12.5, 12.8, 12.10). Additional specimens from the Aftenstjernesø Formation in southern Peary Land were described by Skovsted et al. (2004).

Remarks.—*Triplicatella sinuosa* Skovsted, Peel, and Atkins, 2004 was described by Skovsted et al. (2004) on the basis of opercula from the upper Bastion Formation of North-East Greenland and the Aftenstjernesø Formation of North Greenland. Illustrated specimens from the Aftenstjernesø Formation (Skovsted et al., 2004, fig. 3A–F) were collected in southern Peary Land, but the species was also recorded from southern Lauge Koch Land. The distinctive folds at the dorsum (Figs. 4.2, 12.8), projecting into the shell interior as pseudo-cardinal processes (Fig. 12.5), distinguish the species from the co-occurring *Triplicatella disdoma* where a prominent transverse bar lies dorsally on the internal surface (Fig. 12.2, 12.7).
   Triplicatella papilio Kouchinsky in Kouchinsky et al., 2015 from the uppermost Emyaksin Formation (Cambrian

Series 2, Botoman Stage) of northern Siberia lacks the small median fold between the two major folds on the dorsal margin characteristic of *Triplicatella sinuosa* (Figs. 4.2, 12.8).

Triplicatella cf. *T. xinjia* Pan et al., 2019
Figure 12.3, 12.4

Holotype.—NIGPAS 167850, Xinji Formation, Sanjianfang, Ye County, Henan Province, China (Pan et al., 2019, fig. 6I).

Occurrence.—Xinja Formation of North China, Cambrian Stage 3–4 (Pan et al., 2019) and Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Materials.—PMU 36881 from GGU sample 315045.

Remarks.—This single operculum is reminiscent of *Triplicatella xinjia* Pan et al., 2019 from the Xinji Formation (Cambrian Series 2) of North China in its oblong form and distribution of folds, although the latter is taller and with deeper dorsal folds.

operculum sp. 1
Figure 11.9, 11.10

Occurrence.—Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Materials.—PMU 36949 from GGU sample 315045.

Remarks.—The cardinal processes and pair of clavicles in this single circular specimen are robust, blade-like, with the latter slightly longer than the former (Fig. 11.9). All four projections overhang the weakly expressed clavicular ring, which is obscure ventrally.

operculum sp. 2
Figure 9.9, 9.11

Occurrence.—Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Materials.—PMU 36932 from GGU sample 315045.

Remarks.—This circular, almost flat operculum has a sub-central summit with a broad, shallow fold running towards the presumed dorsum (Fig. 9.9). It is ornamented with comarginal growth lines near the periphery.

Phylum Mollusca Cuvier, 1797
Subphylum Aculifera Hatschek, 1891
Order Sachitida He, 1980
Genus *Hippopharangites* Bengtson in Bengtson et al., 1990

Type species.—*Hippopharangites dailyi* Bengtson in Bengtson et al., 1990 from Cambrian (Terreneuvian and Series 2) of South Australia.

Hippopharangites groenlandicus new species
Figure 13.1–13.13

2020c *Hippopharangites* sp. Peel, fig. 7A–D.

Holotype.—PMU 36061 from GGU sample 315045, Aftenstjernesø Formation, Navarana Fjord, Cambrian Series 2, Stage 4.

Diagnosis.—Species of *Hippopharangites* in which sclerites have a rounded termination and elliptical to sub-rhomboid basal facet; the concave surface with faint transverse ribs.

Occurrence.—Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Description.—Sclerites long and tapering, blade-like, curving through ~60–90° from the proximal basal facet towards the rounded distal termination (Fig. 13.2, 13.4). Cross-section of blade elliptical, inflated on the convex surface, but only shallowly convex on the concave surface. Basal facet transversely elliptical to sub-rhomboid with central foramen (Fig. 13.5, 13.9). Convex surface with irregular rows of rounded scales with distal scales overlain by more proximal scales (Fig. 13.2, 13.7). Concave surface ornamented by slightly irregular, flattened transverse ribs.

Etymology.—From Grønland, the Danish name for Greenland.

Materials.—PMU 36061, holotype, PMU 36062, PMU 36063, PMU 36961–PMU 36966 and four other sclerites from GGU sample 315045.

Remarks.—Specimens from Navarana Fjord were illustrated by Peel (2020c, fig. 7A–D). They differ from the type species *Hippopharangites dailyi* Bengtson in Bengtson et al., 1990, originally described from the Parara Limestone (Cambrian Stage 3) of South Australia (Bengtson et al., 1990), in having a more elliptical cross-section and a rounded, rather than pointed, termination. In addition, sclerites of *Hippopharangites groenlandicus* n. sp. are often more strongly curved adjacent to the basal facet (Fig. 13.1). The concave surface does not carry tubercles, as reported in *Hippopharangites dailyi* by Bengtson et al. (1990), but is traversed by slightly irregular ribs.

Hippopharangites dailyi was also described from the underlying Kulpara and Horse Gulley limestones by Bengtson et al. (1990) and Demidenko (2001). A *Hippopharangites dailyi* Zone within strata considered to represent the Atdabanian Stage of Siberian usage (Cambrian Stage 3) was established, but the nominate species was also recorded within the overlying *Halkieria parva* Zone of the Botoman Stage (Cambrian Stage 4). Betts et al. (2016) did not employ these zones, but introduced a new scheme and it appears that *Hippopharangites dailyi* ranges through the *Kulparina rostrata* (Terreneuvian, Stage 2), *Micrina etheridgei*, and *Dailyatia odyssei* Zones of Betts et al. (2016), the latter terminating at or near the base of Cambrian Series 2, Stage 4 (Betts et al., 2018, fig. 27). Thus, it seems that *Hippopharangites groenlandicus* n. sp. from North Greenland appears in the uppermost part of the range of *Hippopharangites dailyi* or succeeds it.

Poorly preserved specimens from Cambrian Series 2 of New York State and Québec illustrated as *Halkieria* sp. by Landing and Bartowski (1996) and Landing et al. (2002), respectively, may belong here.

Vinther (2009, text-fig. 4) illustrated specimens from South Australia similar to *Hippopharangites* that show numerous phosphate-infilled pores extending from the inner cavity through the shell wall. Similar structures are preserved in *Hippopharangites groenlandicus* n. sp. from Navarana Fjord (Fig. 13.6, 13.13), although corresponding pores on the sclerite exterior surface have not been observed due to diagenetic coating with phosphate.

Order Palaeoloricata Bergenhayn, 1955
Family Mattheviidae Walcott, 1886
Genus *Qaleruaqia* Peel, 2020c

Type species.—*Qaleruaqia sodermanorum* Peel, 2020c, from the Aftenstjernesø Formation, Navarana Fjord, North Greenland, Cambrian Series 3, Stage 4.

Remarks.—Peel (2020c) considered *Qaleruaqia* to be the oldest known palaeoloricate, occurring ca. 20 Ma before *Matthevia* Walcott, 1886, which was originally described from the Furongian of New York (Walcott, 1885, 1886; English, 2002). However, an Ordovician species of *Matthevia* was identified by Pojeta et al. (2005). When considered to be the oldest palaeoloricate, *Matthevia* held a central position in discussions concerning the origin of aplacophorans and polyplacophorans (Vendrasco and Runnegar, 2004; Pojeta et al., 2010; Vinther et al., 2012, 2017). Various reconstructions based on its disarticulated plates have been proposed, but generally it is accepted as a serially plated mollusk (Vendrasco and Runnegar, 2004). The reconstruction reproduced by Vinther (2014, fig. 2) and Vinther et al. (2012, fig. 4) portrays an eight-plated form,
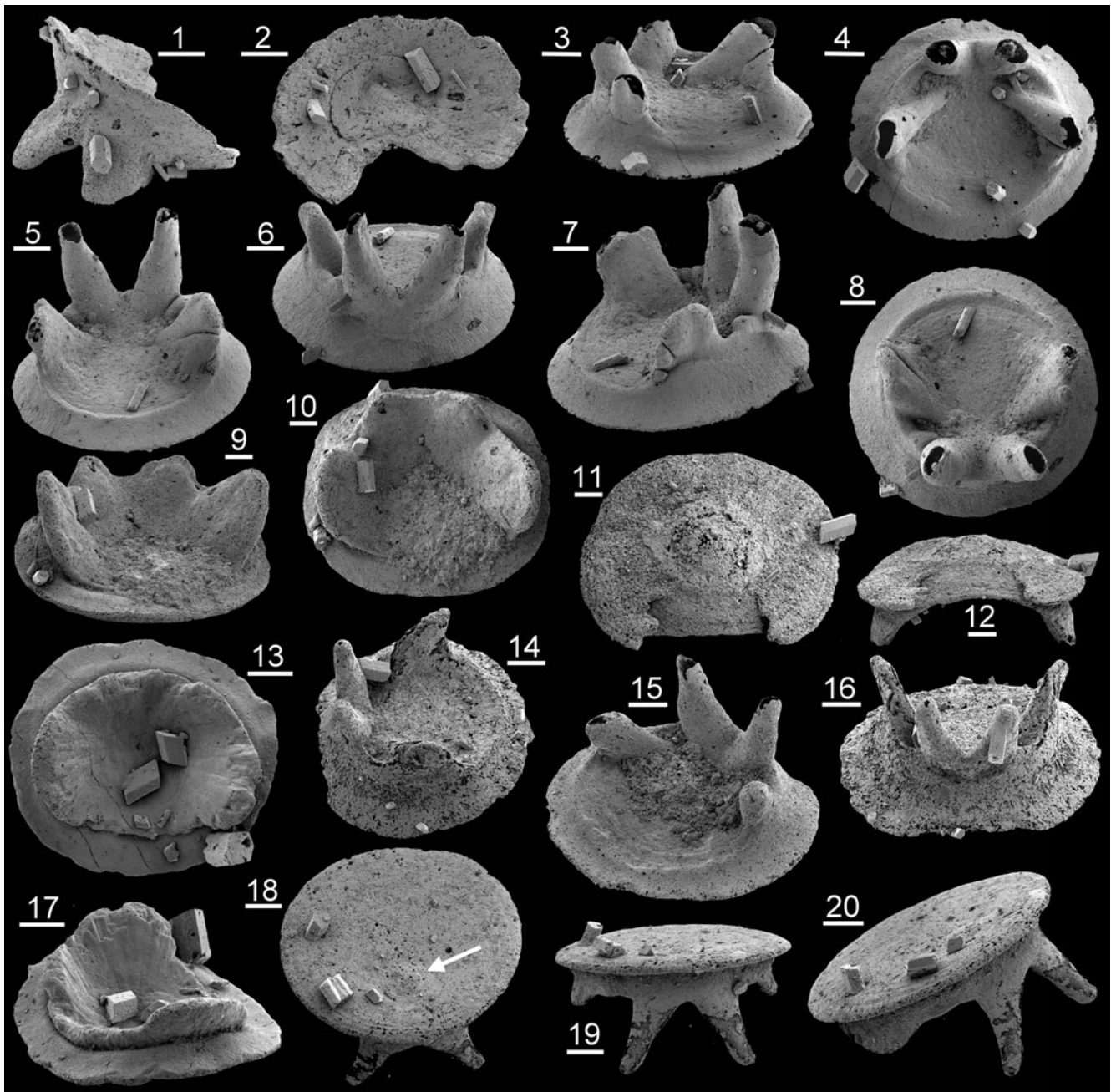
Figure 11. Hyolith opercula from GGU sample 315045, Aftenstjernesø Formation, Navarana Fjord, Cambrian Series 2, Stage 4. (**1, 2**) *Neogloborilus* sp., PMU 36943 in oblique lateral (**1**) and external (**2**, broken edge) views; (**3–8, 14–16**) *Conotheca*? sp. 1, internal views of opercula; (**3, 4**) PMU 36944; (**5–8**) PMU 36945; (**14**) PMU 36946; (**15**) PMU 36947; (**16**) PMU 36948; (**9, 10**) operculum sp. 1, PMU 36949, internal surface; (**11–13, 17**) Allathecid sp. 1; (**11, 12**) PMU 36950, external surface; (**13, 17**) PMU 36951, internal surface; (**18–20**) *Conotheca laurentiensis* Landing and Bartowski, 1996, PMU 36952, oblique views with initial shell arrowed in (**18**). Scale bars: 200 μm (**1, 2**), all others 100 μm.

as conventionally assumed in polyplacophorans. However, only seven plates are preserved in the supposed Silurian aplacophoran *Kulindroplax perissokomos* Sutton et al., 2012.

On the basis of comparisons with *Matthevia*, head and intermediate plates were recognized in *Qaleruaqia* by Peel (2020c), although the number of intermediate plates and the eventual presence of a morphologically distinct tail plate have not been established.

Qaleruaqia sodermanorum Peel, 2020c
Figures 13.14–13.19, 15.9–15.11

2020c   *Qaleruaqia sodermanorum* Peel, p. 131, figs. 4–6.

Holotype.—PMU 36057, intermediate plate from GGU sample 315045, Aftenstjernesø Formation, Navarana Fjord, Cambrian Series 2, Stage 4.

Occurrence.—Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Materials.—Head plate: PMU 36060; intermediate plates: PMU 36057–PMU 36059, holotype and paratypes, all from GGU sample 315045.

Remarks.—*Qaleruaqia sodermanorum* was described by Peel (2020c) from GGU sample 315045 on the basis of rare disarticulated head and intermediate plates. The head plate resembles that of *Matthevia variablis* Walcott, 1885 and *M. wahwahensis* Vendrasco and Runnegar, 2004 from the Furongian of USA (Runnegar et al., 1979; Vendrasco and Runnegar, 2004). Intermediate plates of *Matthevia* differ from *Qaleruaqia sodermanorum* in tapering strongly towards the posterior and being massively thickened, with one or two deep lacunae (Yochelson, 1966; Vendrasco and Runnegar, 2004; Pojeta et al., 2005). *Qaleruaqia sodermanorum* is relatively thin shelled with only a single shallow lacuna, in which respect it more closely resembles *Chelodes* Bergenhayn, 1955.

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Order and family uncertain
Genus *Ocruranus* Liu, 1979
</div>

Type species.—*Ocruranus finial* Liu, 1979 from the Zhongyicun Member, Meisuchun Stage, Yunnan, South China (Qian and Bengtson, 1989, p. 103).

Remarks.—Thorough revisions of the systematics of *Ocruranus* Liu, 1979 and exhaustive synonymies were given by Qian and Bengtson (1989), Vendrasco et al. (2009), and Parkhaev and Demidenko (2010). Records of *Ocruranus* from the Bastion Formation (Stage 4) of North-East Greenland by Peel and Skovsted (2005) were revisited by Vendrasco et al. (2009) who suggested only tentative assignment to the genus. Skovsted et al. (2012) transferred the Greenland species and *Ocruranus trulliformis* (Jiang, 1980) to *Emargimantus* Skovsted, Brock and Topper, 2012.

Vendrasco et al. (2009, text-fig. 2) considered that *Ocruranus* represented the tail plate in a polyplacophoran-like mollusk, in which interpretation the emarginate, shallowly concave sub-apical surface lies at the anterior (right in Fig. 15.1). They recognized three types of plate with intermediate plates of *Gotlandochiton*? *minimus* Yu, 1987 lying between a head plate of *Eohalobia* Jiang in Luo et al., 1982 and a tail plate of *Ocruranus*. In contrast, Parkhaev (2008, fig. 3.3) interpreted *Ocruranus* as the anterior plate of a halkieriid following comparison to material figured by Conway Morris and Peel (1995), with the subapical surface interpreted as posterior. Skovsted et al. (2012) assigned *Emargimantus* to the Class Helcionelloida Peel, 1991a in which Peel (1991a, b) interpreted this sub-apical surface as posterior.

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Ocruranus? *kangerluk* new species
Figure 15.1–15.8
</div>

Holotype.—PMU 36979 from GGU sample 315045, Aftenstjernesø Formation, Navarana Fjord, Cambrian Series 2, Stage 4.

Diagnosis.—Seemingly a species of *Ocruranus* with blunt rounded apex; short sub-apical surface with broad fold and corresponding marginal sinus.

Occurrence.—Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Description.—Sub-circular in dorsal view (Fig. 15.8) with height just less than diameter. Slightly curved in lateral view (Fig. 15.1), with well-developed supra-apical and sub-apical surfaces; blunt rounded apex closer to sub-apical margin. Sub-apical surface with a variably expressed broad fold that passes gradually into the lateral areas and forms the locus of a broad, shallow sinus in the margin (Fig. 15.7). Shell thick, with closely spaced, lamellose growth lines that may be wrinkled perpendicular to the growing edge.

Etymology.—From kangerluk, the Greenlandic name for fiord (Danish: fjord), referring to Navarana Fjord.

Materials.—PMU 36979, holotype, PMU 36977 and PMU 36978, paratypes, and five shells from GGU sample 315045.

Remarks.—*Ocruranus*? *kangerluk* n. sp. is closely similar to one specimen of *Ocruranus trulliformis* (Jiang, 1980) illustrated by Qian and Bengtson (1989, fig. 69A) from the Zhongyicun Member, Meishucun Stage, Yunnan, South China, in terms of the width of the sub-apical fold, but this fold is narrower in a second specimen (Qian and Bengtson, 1989, fig. 69B). *Ocruranus*? *kangerluk* n. sp. differs from both of these in its less-pointed apex, shorter sub-apical surface, and deeper sub-apical sinus. Specimens of *Ocruranus trulliformis* illustrated by Parkhaev and Demidenko (2010, pl. 44) from the same general locality are more conical in form, with flattened lateral areas, and somewhat pointed at the sub-apical margin.

Kouchinsky et al. (2017, fig. 35) illustrated internal molds referred to *Purella cristata* Missarzhevsky, 1974 from the early Cambrian Medvezhaya Formation, some of which show a similar tendency to develop a broad fold on the sub-apical surface. *Ocruranus*? *kangerluk* n. sp. is distinguished by the presence of a broad emargination in its sub-apical marginal and lacks any indication of the scaly ornamentation characteristic of *Purella* Missarzhevsky, 1974.

Vendrasco et al. (2009) only tentatively assigned *Ocruranus trulliformis* to *Ocruranus* because it is taller than the type species *Ocruranus finial* and lacked evidence of association with other elements in a multi-element polyplacophoran scleritome of *Ocruranus-Eohalobia* type. Other, similar, constituent plate types have not been recognized together with *Ocruranus*? *kangerluk* n. sp. in GGU sample 315045, with the exception of a single elongate form referred with much hesitation to *Ocruranus* sp., but sample size is small. Skovsted et al. (2012) transferred *Ocruranus trulliformis* to a new genus, *Emargimantus*, with type species *Emargimantus angulatus* Skovsted, Brock, and Topper, 2012 from the Arrowie Basin of South Australia. It was placed together with species from the upper Bastion Formation (Dyeran Stage; Stage 4) of North-East Greenland that Peel
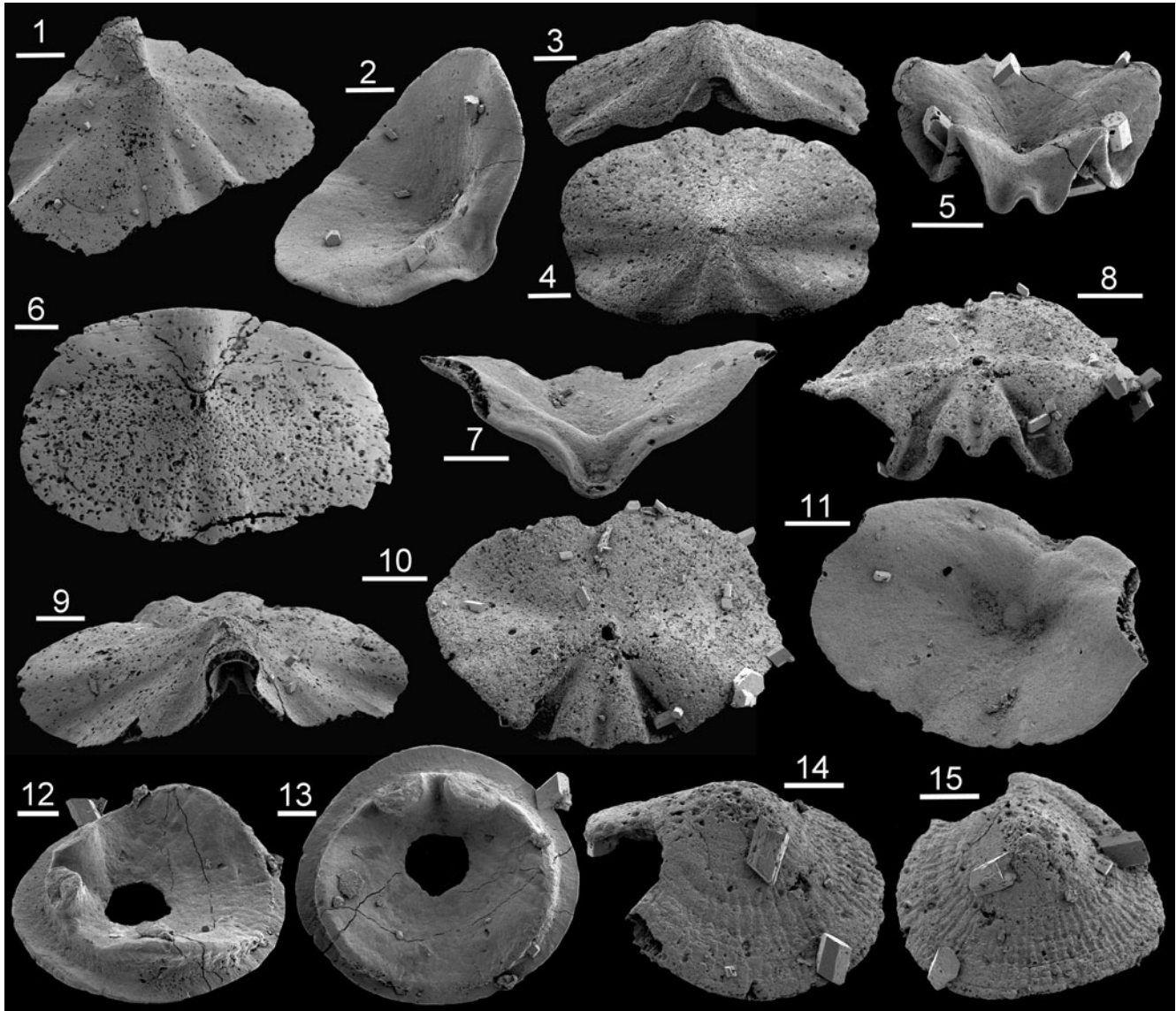
Figure 12. Hyolith opercula from GGU sample 315045, Aftenstjernesø Formation, Navarana Fjord, Cambrian Series 2, Stage 4. (**1, 2, 6, 7, 9, 11**) *Triplicatella disdoma* Conway Morris in Bengtson et al., 1990; (**1, 9**) PMU 36953, oblique views of outer surface; (**2**) PMU 36954, oblique view of inner surface; (**6**) PMU 36955, external surface; (**7, 11**) PMU 36956, oblique vies of inner surface; (**3, 4**) *Triplicatella* cf. *T. xinjia* Pan et al., 2019, PMU 36881, external surface in oblique (**3**) and plan (**4**) views; (**5, 8, 10**) *Triplicatella sinuosa* Skovsted, Peel, and Atkins, 2004; (**5**) PMU 36957, oblique view of inner surface showing folded margin; (**8, 10**) PMU 36958, external surface; (**12, 13**) *Conotheca laurentiensis* Landing and Bartowski, 1996, PMU 36959, inner surface; (**14, 15**) Allathecid sp. 2, PMU 36960, oblique views of outer surface. Scale bars: 100 µm (**12–15**), 200 µm (**1–11**).

and Skovsted (2005) had assigned to *Ocruranus*, and was assigned to Class Helcionelloida Peel, 1991a.

　　Ocruranus sp. of Peel and Skovsted (2005, fig. 4) from the upper Bastion Formation of Albert Heim Bjerge, North-East Greenland was only tentatively assigned to *Emargimantus* on account of its lower shell, in which feature it also differs from *Ocruranus*? *kangerluk* n. sp. It differs from the latter also on account of its more centrally placed apex and deeper, more V-shaped sinus in the sub-apical surface. Both species have thick shells, but *Ocruranus* sp. lacks the broad sub-apical fold seen in *Ocruranus kangerluk* n. sp. (Fig. 15.7). Vendrasco et al. (2009) questioned the assignment of *Ocruranus* sp. from the Bastion Formation on account of its granular shell structure, but Peel and Skovsted (2005) noted that only a phosphatic

coating of the original, now dissolved, shell was preserved. *Ocruranus* sp. is transferred herein to *Inughuitoconus* n. gen.

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Ocruranus? sp.
Figures 9.10, 9.13

</div>

Occurrence.—Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Materials.—PMU 36933 from GGU sample 315045.

Remarks.—As preserved, this elongate internal mold is almost twice as long as wide, with the bluntly rounded apex located close to the sub-apical margin (Fig. 9.13). The supra-apical

surface is separated from the sub-apical surface by an angular change in slope; a broad, shallow median sinus occupies the supra-apical margin. The apex and sub-apical surface are smooth, but broad, poorly defined ridges with low tubercles slope from the apical area across the flanks of the supra-apical surface (Fig. 9.10). Medial and distal ornamentation on the supra-apical surface consists of irregular granules.

In its lateral profile and the form of its sub-apical surface, this elongate internal mold resembles a low specimen of *Ocruranus trulliformis* (Jiang, 1980) illustrated by Parkhaev and Demidenko (2010, pl. 45, fig. 1c), and specimens illustrated as *Ocruranus finial* Liu, 1979 by Qian and Bengtson (1989, fig. 66A₃, B₃) and Vendrasco et al. (2009, pl. 6, fig. 6). These Meishucunian species, however, are taller and more rounded in plan view. There is also some resemblance to the operculum of hyolithids, with the sub-apical surface equivalent to the dorsal cardinal shield and the supra-apical surface to the conical shield. However, the angle of divergence of the sides of the supra-apical surface is much narrower than in the conical shield of hyolithids, and there is no indication of cardinalia.

Genus *Inughuitoconus* new genus

Type species.—*Inughuitoconus borealis* n. sp., Aftenstjernesø Formation, Navarana Fjord, Cambrian Series 2, Stage 4. Masculine.

Diagnosis.—As for the type species, by monotypy.

Occurrence.—Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Etymology.—For the Inughuit, the native Inuit inhabitants of northern Greenland.

Remarks.—*Tunudiscus* Skovsted, 2006a, from the Bastion Formation of North-East Greenland, is distinguished by its lower circular conical shell with thin growth lamellae. In terms of the robust shell, *Inughuitoconus* n. gen. resembles the contemporaneous *Ocruranus*? *kangerluk* n. sp., but the latter is both taller and more strongly coiled.

Inughuitoconus borealis new species
Figure 7.14–7.18

Holotype.—PMU 36913 from GGU sample 315045, Aftenstjernesø Formation, Navarana Fjord, Cambrian Series 2, Stage 4.

Diagnosis.—Low, circular in dorsal view, cap-shaped, with blunt rounded sub-central apex and thick shell. Sub-apical surface slightly flattened relative to supra-apical and lateral surfaces, culminating in a broad marginal emargination. Ornamentation of slightly irregular comarginal cords with narrow interstices. Inner surface with obscure radial ridges near the periphery. Shell originally calcareous, with radially fibrous structure.

Occurrence.—Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Description.—The low, circular, thick, cap-shaped shell has a blunt sub-central apex. Supra-apical and lateral surfaces are shallowly convex, with the slightly flattened sub-apical surface culminating in a broad marginal emargination. Ornamentation consists of slightly irregular comarginal cords with narrow interstices. Inner surface with obscure radial ridges near the periphery. Shell originally calcareous, with radially fibrous structure that may form a weak external radial striation.

Etymology.—From *borealis*, Latin, meaning northern.

Materials.—In addition to the holotype, PMU 36914, paratype, from GGU sample 315045.

Remarks.—*Inughuitoconus borealis* n. gen. n. sp. is similar to two specimens from the upper Bastion Formation of Albert Heim Bjerge that Peel and Skovsted (2005, fig. 4) and Skovsted et al. (2012) referred to *Ocruranus* sp. They are here referred to the new genus *Inughuitoconus* sp. on account of their low circular form.

Subphylum Conchifera Gegenbaur, 1878
Class Helcionelloida Peel, 1991a
Order Helcionellida Geyer, 1994
Family Helcionellidae Wenz, 1938

Genus *Capitoconus* Skovsted, 2004

Type species.—*Capitoconus inclinatus* Skovsted, 2004, from the Bastion Formation, North-East Greenland, Cambrian Series 2, Stage 4.

Capitoconus artus Skovsted, 2004
Figure 14.7, 14.8

2004 *Capitoconus artus* Skovsted, p. 20, fig. 5A–L.

Holotype.—MGUH 26976 from GGU sample 314835, upper Bastion Formation, Albert Heim Bjerge, North-East Greenland (Skovsted, 2004, fig. 5A, B, F).

Occurrence.—Upper Bastion Formation, North-East Greenland and Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Materials.—PMU 36973 from GGU sample 315045.

Remarks.—This single internal mold of the early growth stage shows the swollen elongate protoconch and lamellose comarginal ornamentation characteristic of *Capitoconus artus* Skovsted, 2004 from the Bastion Formation, North-East Greenland (Skovsted, 2004, 2006a). Kouchinsky et al. (2015) described a similar form from the uppermost Emyaksin Formation (Cambrian Stage 4, Botoman Stage) to *Parailsanella* sp. 2, but the lamellar comarginal ornamentation in that is more subdued.
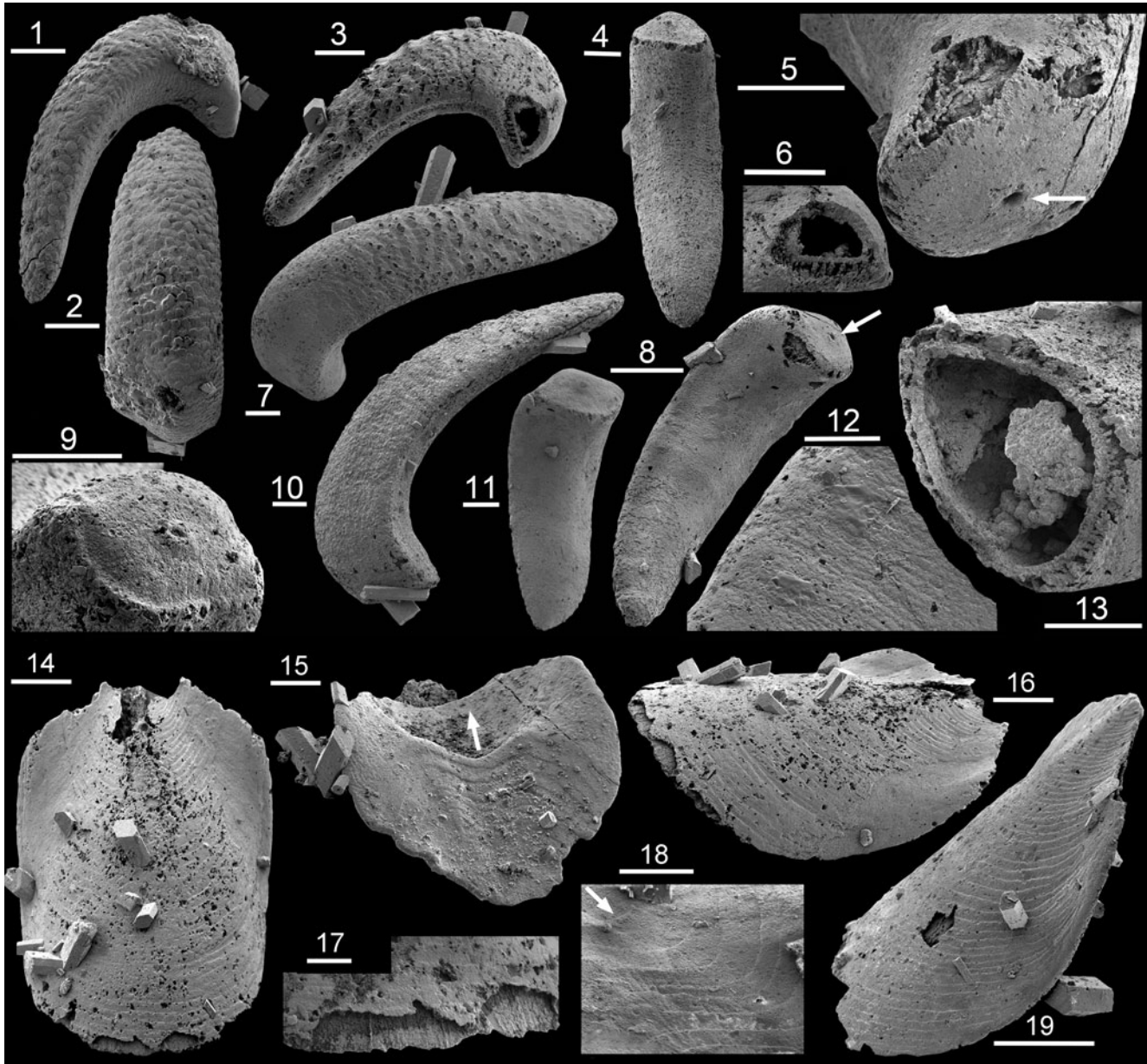
Genus *Davidonia* Parkhaev, 2017

Figure 13. Stem-group Aculifera? from GGU sample 315045, Aftenstjernesø Formation, Navarana Fjord, Cambrian Series 2, Stage 4. (**1–13**) *Hippopharangites groenlandicus* n. sp., individual sclerites; (**1, 2**) PMU 36061, holotype; (**3, 6**) PMU 36961; (**4**) PMU 36962; (**5, 8, 12**) PMU 36062, showing central foramen (**5, 8,** arrows) and detail of ornamentation on concave surface (**12**); (**7**) PMU 36963; (**9**) PMU 36964, basal facet with central foramen; (**10**) PMU 36063; (**11**) PMU 36965; (**13**) PMU 36966, cross-section of shell showing poorly preserved pores in wall; (**14–19**) *Qaleruaqia sodermanorum* Peel, 2020c from GGU sample 315045, Aftenstjernesø Formation, Navarana Fjord, Cambrian Series 2, Stage 4; (**14, 16, 17**) PMU 36057, holotype, dorsal (**14**) and lateral (**16**) views, with detail of inner fibrous layer (**17**); (**15**) PMU 36058, apical area, arrow indicates anterior; (**18, 19**) PMU 36059, dorso-lateral view (**19**) and detail of lamellar ornamentation on apical area (**18**, arrow indicates anterior). Scale bars: 50 μm (**17, 18**), 100 μm (**1–13, 15**), 200 μm (**14, 16, 19**).

Type species.—*Mackinnonia davidi* Runnegar in Bengtson et al., 1990, from the lower Cambrian Parara Limestone, Stansbury Basin, South Australia, Cambrian Series 2, *Dailyatia odyssei* Zone (non *Mackinnonia* Janiszewska, 1967).

Remarks.—Parkhaev (2017) regarded *Mackinnonia* Runnegar in Bengtson et al., 1990 as a junior homonym of the myriosporid sporozoan *Mackinnonia* Janiszewska, 1963, and introduced *Davidonia* as a replacement name. However, Jackson and Claybourn (2018) considered *Mackinnonia* Janiszewska, 1963 to be a nomen nudum and maintained *Mackinnonia* Runnegar in Bengtson et al., 1990. Claybourn et al. (2019) cited Jackson and Claybourn (2018), but maintained *Davidonia* without discussion. Following Jackson and Claybourn (2018), Geyer et al. (2019, p. 225) concluded that *Davidonia* Parkhaev, 2017 is a junior synonym of *Mackinnonia* Runnegar in Bengtson et al., 1990 due to the unavailable status of Janiszewska's (1963) species. He noted, however, the subsequent usage of *Mackinnonia* by Janiszewska (1967). A protozoan family Mackinnoniidae was also erected by Vivier (1981).

Mackinnonia Janiszewska, 1963 is a nomen nudum because it is only mentioned in the text (Janiszewska, 1963) without any form of characterization other than its association with an equally unavailable species epithet *tubificis*. *Mackinnonia* was diagnosed, fully described, and compared to other taxa by Janiszewska (1967), although she attributed its authorship to Janiszewska (1963). As described, the genus included only a single species, with the characters of the genus, and *Mackinnonia tubificis* Janiszewska, 1967 is therefore the type species of *Mackinnonia* Janiszewska, 1967, by monotypy. Thus, *Mackinnonia* Runnegar in Bengtson et al., 1990 is a junior homonym of *Mackinnonia* Janiszewska, 1967, and the substitute name *Davidonia* proposed by Parkhaev (2017) is accepted.

<div align="center">

Davidonia rostrata (Zhou and Xiao, 1984)
Figure 14.9

</div>

1984　*Mellopegma rostratum* Zhou and Xiao, p. 132, pl. 3, figs. 7–10.
1990　*Mackinnonia davidi* Runnegar in Bengtson et al., p. 234, figs. 159, 160J.
2001　*Mackinnonia rostrata*; Parkhaev, p. 176, pl. 40, 41.
2004　*Mackinnonia rostrata*; Skovsted, p. 16, fig. 3A–H.
2018　*Mackinnonia rostrata*; Jackson and Claybourn.
2019　*Davidonia rostrata*; Claybourn et al., p. 444, fig. 4.6–4.14 (with additional references).
2019a　*Davidonia rostrata*; Li et al., p. 17, fig. 11.

Holotype.—Geological Institute, Anhui Province, specimen number 800059, Yutaishan Formation, Anhui Province, North China (Zhou and Xiao, 1984, pl. 3, figs. 7–10).

Occurrence.—See Claybourn et al (2019) and Li et al. (2019a) and subsequently the Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Materials.—PMU 36974 from GGU sample 315045.

Remarks.—Li et al. (2019a, fig. 11) illustrated the wide variation in degree of expression of comarginal ribbing, from smooth to coarsely rugose, on internal molds from the Xinji Formation (Cambrian Series 2) of North China. *Davidonia rostrata* from Navarana Fjord lies near the middle of this range also in the degree of concavity of its sub-apical surface (Fig. 14.9). In both respects it compares closely to specimens illustrated by Skovsted (2004, fig. 3A–H) from the Bastion Formation of North-East Greenland and by Landing and Bartowski (1996, fig. 5.10–5.18) from the Browns Pond Formation of New York State. Most specimens illustrated by Claybourn et al. (2019) from the Shackleton Limestone of eastern Antarctica are less rugose, whereas those illustrated by Parkhaev (2001) have strongly rugose internal molds.

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Davidonia taconica (Landing and Bartowski, 1996)
Figure 14.10–14.13

</div>

1996　*Stenotheca taconica* Landing and Bartowski, p. 753, figs. 5.5, 5.7–5.9, 10.2, 10.3.

2001　*Aequiconus taconica*; Parkhaev, p. 138.
2002　*Stenotheca taconica*; Landing et al., fig. 8.4.
2004　*Mackinnonia taconica*; Skovsted, p. 16, figs. 3I–R, 4A–C.
2007　*Mackinnonia taconica*; Skovsted and Peel, p. 734, fig. 4A.
2018　*Mackinnonia taconica*; Jackson and Claybourn.
2019　*Davidonia taconica*; Claybourn et al., p. 444.

Holotype.—NYSM 15529, Browns Pond Formation, Claverack, New York State (Landing and Bartowski, 1996, fig. 5.7–5.9).

Occurrence.—New York State, Québec, western Newfoundland, North-East Greenland and Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Materials.—PMU 36975 and PMU 36976 from GGU sample 315045.

Remarks.—Parkhaev (2001) designated *Stenotheca taconica* Landing and Bartowski, 1996 as type species for a new genus, *Aequiconus* Parkhaev, 2001, but Skovsted (2004) placed this in synonymy with *Mackinonnia* Runnegar in Bengtson et al., 1990, currently renamed *Davidonia* (see above). Type material of *Stenotheca taconica* from the Browns Pond Formation of New York State is almost pyramidal in lateral perspective, with the apex located centrally, whereas specimens from Navarana Fjord are strongly coiled with the apex close to the sub-apical margin (Fig. 14.12). In consequence, the supra-apical surface is strongly convex in lateral view while it is only shallowly convex in material from New York and in large specimens illustrated by Skovsted (2004, fig. 3I). It is likely that this difference reflects ontogenetic change resulting from expansion of the logarithmic spire of the shell, with early growth stages more strongly coiled than later growth stages. A detailed morphometric comparison of *Davidonia rostrata* and *Davidonia taconica* was carried out by Jackson and Claybourn (2018).

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Family Stenothecidae Runnegar and Jell, 1980

</div>

Remarks.—A detailed analysis of stenothecids was given by Vendrasco et al. (2011b). They excluded *Anabarella* Vostokova, 1962 from the Family Stenothecidae on account of its much more strongly coiled shell. However, *Anabarella*? *navaranae* n. sp., although much younger than the type species *Anabarella plana* Vostokova, 1962, may bridge that morphological gap and the genus is tentatively retained within Stenothecidae.

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Genus *Stenotheca* Salter in Hicks, 1872

</div>

Type species.—*Stenotheca cornucopia* Salter in Hicks, 1872 from the middle Cambrian of Pembrokeshire, Wales, U.K.

<div align="center">

Stenotheca? *higginsi* new species
Figure 14.1–14.3, 14.5, 14.6

</div>

Holotype.—PMU 36969 from GGU sample 315045, Aftenstjernesø Formation, northern Lauge Koch Land, North Greenland, Cambrian Series 2, Stage 4.
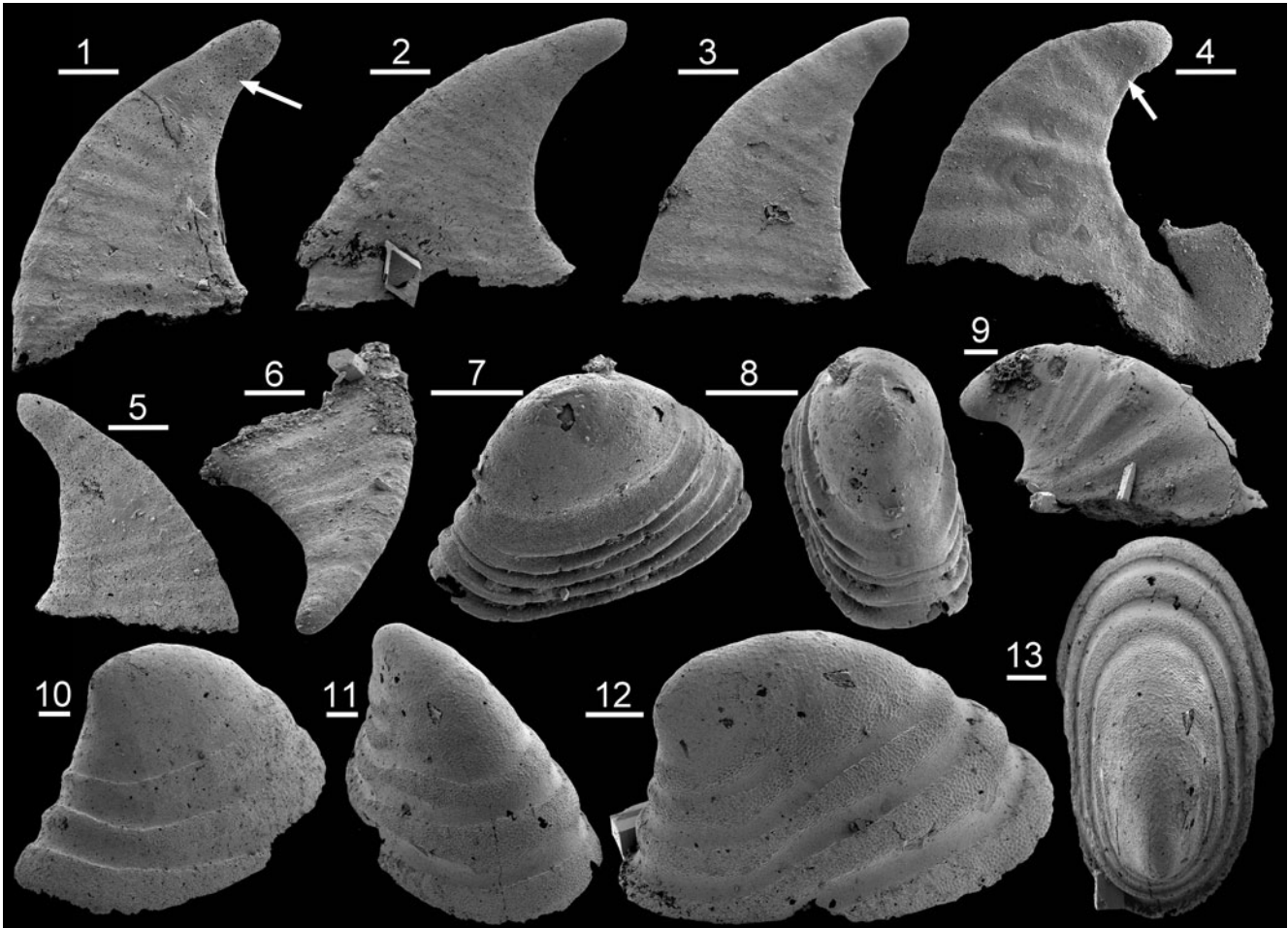
Figure 14. Helcionellid mollusks from GGU sample 315045, Aftenstjernesø Formation, Navarana Fjord, Cambrian Series 2, Stage 4. (**1–3, 5, 6**) *Stenotheca*? *higginsi* n. sp.. internal molds; (**1**) PMU 36967, lateral view with shallow apical constriction (arrow); (**2**) PMU 36968, lateral view; (**3**) PMU 36969, holotype, lateral view; (**5**) PMU 36970, lateral view; (**6**) PMU 36971, oblique lateral view; (**4**) PMU 36972 *Anabarella*? *navaranae* n. sp., holotype, internal mold in lateral view with shallow apical constriction (arrow); (**7, 8**) *Capitoconus artus* Skovsted, 2004, PMU 36973, internal mold; (**9**) *Davidonia rostrata* (Zhou and Xiao, 1984), PMU 36974, internal mold in lateral view; (**10–13**) *Davidonia taconica* (Landing and Bartowski, 1996), internal molds; (**10**) PMU 36975; (**11–13**) PMU 36976, oblique lateral (**11, 12**) and dorsal (**13**) views. Scale bars = 100 μm.

Diagnosis.—Bilaterally symmetrical, strongly laterally compressed, open coiled through almost one quarter of a whorl; upright shell expanding slowly in plane of symmetry; comarginal ornamentation.

Occurrence.—Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Description.—The slowly expanding bilaterally symmetrical shell is open coiled through less than a quarter of a whorl and is strongly laterally compressed. In lateral profile it is upright, with height slightly greater than overall length (Fig. 14.1), and with the blunt apex overhanging the sub-apical margin. A shallow constriction on the internal mold delimits the initial, more gradually expanding, growth stage from the later shell (Fig. 14.1, arrow). Aperture simple, without emarginations. Ornamentation of low, broad, comarginal ribs, which may become shallowly concave on lateral areas (Fig. 14.3).

Etymology.—For Anthony ('Tony') K. Higgins (1940–2018), whose regional geological studies around Navarana Fjord,

during a life-long career with the Geological Survey of Greenland, formed a precursor to the present paper.

Materials.—In addition to the holotype, PMU 36967, PMU 36968, PMU 36970–PMU 36971, paratypes, from GGU sample 315045.

Remarks.—*Stenotheca*? *higginsi* n. sp. is known from internal molds showing a much lower rate of expansion than the holotype of the type species from Pembrokeshire, Wales (Cobbold, 1934, pl. 23, fig. 1a, b), and consequently a taller, narrower shell. Hence the assignment to the poorly known genus is questioned. However, a reconstruction of an additional fragment of a specimen illustrated by Cobbold (1934, pl. 23, fig. 3) is much taller than the holotype. In lateral profile *Stenotheca*? *higginsi* n. sp. is similar to specimens described as *Stenotheca* sp. by Bengtson et al. (1990) from the Oraparinna Shale (Cambrian Stage 4) at Bunyeroo Gorge in the Flinders Range of South Australia, but more laterally compressed. The Australian specimens were referred to *Anuliconus* by Parkhaev (2001, p. 142; 2019, p. 182), but are

much more laterally compressed, with less-prominent comarginal ribs than *Anuliconus magnificus* Parkhaev, 2001, the type species. In terms of its lateral perspective, *Stenotheca*? *higginsi* n. sp. more closely resembles *Anuliconus truncatus* Parkhaev, 2001, which is stated to be laterally compressed. As regards the degree of lateral compression, *Stenotheca*? *higginsi* n. sp. resembles *Stenotheca drepanoida* (He and Pei in He et al., 1984) from China and Australia (Bengtson et al., 1990; Parkhaev 2001; Li et al., 2019a), *Stenotheca acutacosta* Walcott, 1890, and *Stenotheca norvegica* (Resser, 1938), the latter recently described by Høyberget et al. (2015). However, it differs from these in terms of its upright, more gradually expanding shell and more open coiling. The degree of lateral compression of *Stenotheca*? *higginsi* n. sp. is comparable to that seen in the co-occurring *Anabarella*? *navaranae* n. sp., internal molds of which also have an upright and gradually expanding shell form.

<div align="center">Genus Anabarella Vostokova, 1962</div>

Type species.—*Anabarella plana* Vostokova, 1962, from the Tommotian Stage of Siberia.

<div align="center">Anabarella? navaranae new species
Figure 14.4</div>

Holotype.—PMU 36972 from GGU sample 315045, Aftenstjernesø Formation, Navarana Fjord, North Greenland, Cambrian Series 2, Stage 4.

Diagnosis.—Bilaterally symmetrical, strongly laterally compressed; internal mold with upright, narrow, form due to the low rate of whorl expansion; long sub-apical surface and deep pegma cleft.

Occurrence.—Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Description.—Bilaterally symmetrical, upright, known only from the internal mold that is loosely coiled through about half to three-quarters of a whorl and gradually expanding along the plane of symmetry. Strongly compressed laterally. Bluntly rounded early growth stage is delimited from the later shell by a broad shallow constriction (Fig. 14.4, arrow). Deep cleft corresponding to a pegma separates the long sub-apical surface from its continuation as the sub-apical fold. Lateral areas traversed by comarginal rugae separated by broad, shallow, concavities. Shell outer surface and ornamentation unknown.

Etymology.—For Navarana Mequpaluk Avigah Marsauguq Freuchen (1898?–1921), on the 100th anniversary of her death from the Spanish Flu epidemic. Inughuit wife and expedition companion of Danish explorer Peter Freuchen (1888–1957); their names are perpetuated in Freuchen Land and Navarana Fjord.

Materials.—*Anabarella*? *navaranae* n. sp. is known only from the holotype in GGU sample 315045, but it occurs also

in the Aftenstjernesø Formation of southern Lauge Koch Land and northern Nyeboe Land (J.S. Peel, unpublished observations).

Remarks.—In its upright form and rate of expansion, *Anabarella*? *navaranae* n. sp. closely resembles the contemporaneous *Stenotheca*? *higginsi* n. sp. from which it is distinguished by its greater curvature in lateral view (Fig. 14.4), coarser comarginal ornamentation, and the prominent pegma and fold in the sub-apical margin. *Anabarella*? *navaranae* n. sp. resembles internal molds of *Anabarella argus* Runnegar in Bengtson et al., 1990 from the Ajax Limestone of South Australia in terms of the deep cleft formed by the pegma on the sub-apical surface and lateral compression. It is delimited from *Anabarella argus* by its lower rate of expansion of the shell in the plane of symmetry and consequent more upright form in lateral profile (Fig. 14.4). The sub-apical surface between the apex and the sub-apical fold is also much longer in *Anabarella navaranae* n. sp., and the apex less curved.

Anabarella australis Runnegar in Bengtson et al., 1990 from the Parara Limestone and upper Kulpara Limestone of South Australia (Bengtson et al., 1990) and the Bastion Formation of North-East Greenland (Gubanov et al., 2004) is more tightly coiled through a full whorl, such that the apex lies in contact with the previous whorl, or almost so, as in the Terreneuvian type species (Vostokova, 1962; Gubanov and Peel, 2003). However, these two species are known from specimens with shell preserved, whereas *Anabarella*? *navaranae* n. sp. is known only from the more slender internal molds. The shape difference and variation in shell form between the internal mold and specimens with the shell preserved prompted Parkhaev (2001) and Li et al. (2019b) to place the tightly coiled *Anabarella argus* as a junior synonym of *Anabarella australis*, but *Anabarella*? *navaranae* n. sp. is much less tightly coiled, as evinced by the greater length of the sub-apical surface. Vendrasco et al. (2011b, p. 6) considered *Anabarella australis* to be a stenothecid, while rejecting *Anabarella* from that family.

<div align="center">Family Trenellidae Parkhaev, 2001
Genus Figurina Parkhaev, 2001</div>

Type species.—*Figurina figurina* Parkhaev, 2001, from the Horse Gulley Limestone, Cambrian Series 2, Botoman Stage, of South Australia.

<div align="center">Figurina? polaris new species
Figure 4.7, 4.8</div>

Holotype.—PMU 36887 from GGU sample 315028, Aftenstjernesø Formation, Navarana Fjord, North Greenland, Cambrian Series 2, Stage 4.

Diagnosis.—Tentatively a species of *Figurina* with widely spaced, prominent radial ribs crossed by slightly lamellose comarginal growth lines.
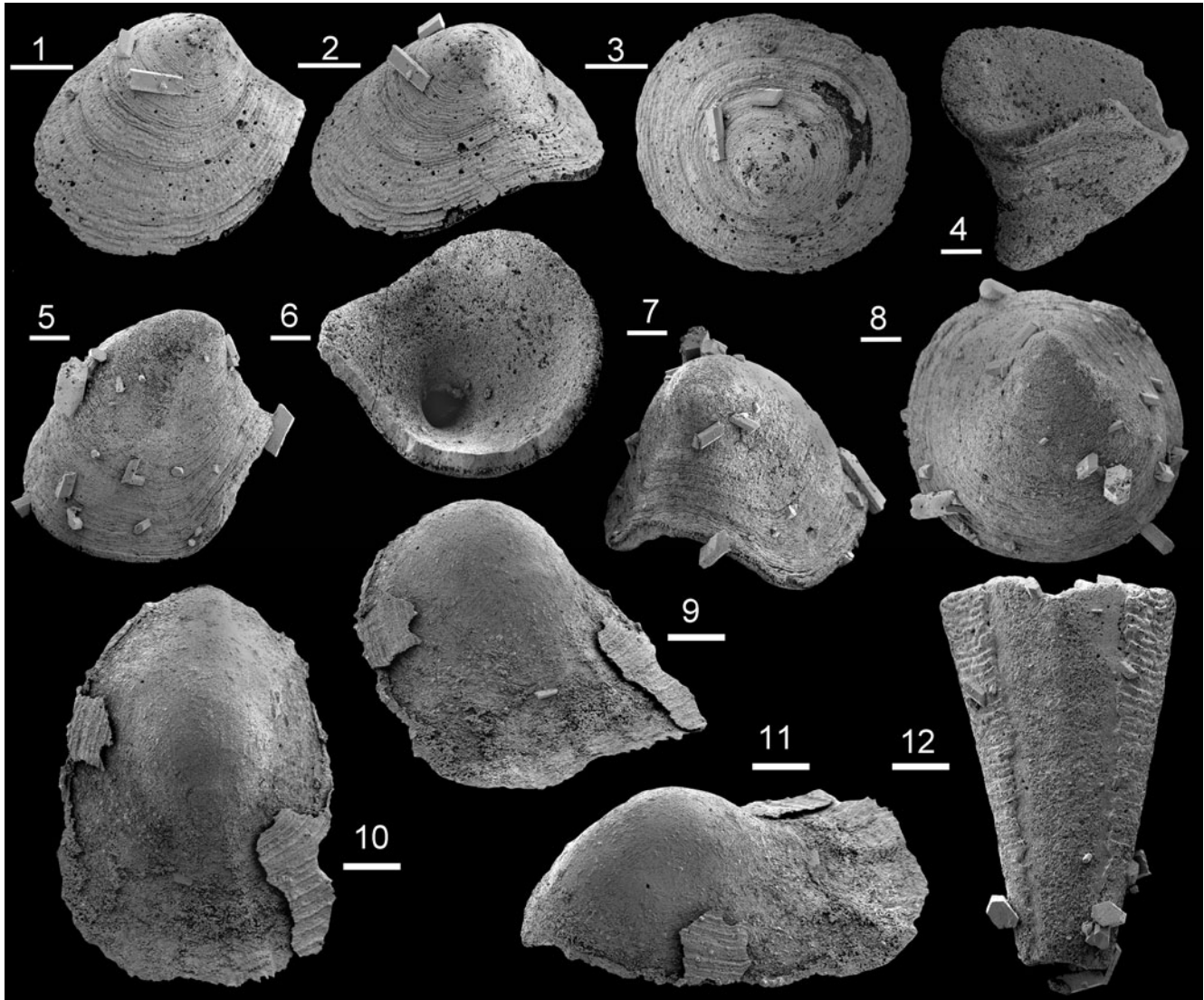
Figure 15. Small shelly fossils from GGU sample 315045, Aftenstjernesø Formation, Navarana Fjord, Cambrian Series 2, Stage 4. (**1–8**) *Ocruranus*? *kangerluk* n. sp.; (**1–3**) PMU 36977, in dorso-lateral view (**1**) that over-emphasizes the curvature of the lateral margin, oblique lateral view of sub-apical surface (**2**), and dorsal view (**3**); (**4, 6**) PMU 36978, oblique apertural views showing thick shell; (**5, 7, 8**) PMU 36979, holotype, in dorso-lateral view (**5**), oblique lateral view of sub-apical surface showing broad sub-apical fold (**7**), and dorsal view (**8**); (**9–11**) *Qaleruaqia sodermanorum* Peel, 2020c, PMU 36060, head plate in oblique posterior (**9**), dorsal (**10**), and oblique lateral (**11**) views; (**12**) *Microcornus*? sp., PMU 36880, hyolith conch. Scale bars = 200 µm.

Occurrence.—Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Description.—Low, oval shell with width about two-thirds of length. Supra-apical surface uniformly shallowly convex in long section; sub-apical surface concave, steeply inclined such that the apex lies above the margin. Ornamentation of widely spaced, prominent radial ribs with rounded upper surfaces, crossed by slightly lamellose comarginal growth lines (Fig. 4.8, arrow).

Etymology.—From Polaris, the North Star.

Materials.—Only the holotype is known from northern Lauge Koch Land, but poorly preserved specimens occur in undescribed collections from southern Peary Land.

Remarks.—Reference of this species to *Figurina* is tentative because definition of the genus (Parkhaev, 2001; Skovsted, 2004) is largely based on characters of the internal mold that are not visible here in the partly exfoliated specimen. *Figurina*? *groenlandica* Skovsted, 2004 from the Bastion Formation of North-East Greenland has a slightly taller, narrower shell with parallel sides, and with the supra-apical surface more strongly curved in lateral view (Skovsted, 2004). It is known mainly from internal molds, often with a partial phosphate coating that may show weak traces of radial ribs. Internal molds assigned to the genus by Parkhaev (2001) have a more strongly overhanging apex; they lack the radial ribs characteristic of *Figurina*? *polaris* n. sp., but may show comarginal corrugations absent in the latter species.

Family Yochelcionellidae Runnegar and Jell, 1976
Genus *Yochelcionella* Runnegar and Pojeta, 1974

Type species.—*Yochelcionella cyrano* Runnegar and Pojeta, 1974, early middle Cambrian, (Ordian); Cambrian Series 3, New South Wales, Australia.

Yochelcionella greenlandica Atkins and Peel, 2004
Figure 4.1

2004	*Yochelcionella greenlandica* Atkins and Peel, p. 3, fig. 2A–Q.
2008	*Yochelcionella greenlandica*; Atkins and Peel, p. 34, figs. 4O, 4P, 7D, 8A–D.

Holotype.—MGUH 27016 from GGU sample 271471, Aftenstjernesø Formation, southern Lauge Koch Land, North Greenland (Atkins and Peel, 2004, fig. 2A–D).

Occurrence.—Québec, New York State, Pennsylvania, MacKenzie Mountains (Canada), and North Greenland, Cambrian Series 2, Stage 4.

Materials.—PMU 36882 from GGU sample 315028.

Remarks.—Erroneous reports of this species from the upper Henson Gletscher Formation of Peary Land by Atkins and Peel (2004) were corrected by Atkins and Peel (2008) and Peel et al. (2016). As currently known, *Yochelcionella greenlandica* is restricted in Greenland to the basal Aftenstjernesø Formation, although it was also reported by Atkins and Peel (2008) from the lower Kinzers Formation of Thomasville, Pennsylvania (Skovsted and Peel, 2010), the Sekwi Formation of the MacKenzie Mountains (Voronova et al., 1987), the Browns Pond Formation of New York State (Landing and Bartowski, 1996), and the "Anse Miranda Formation" of Québec (Landing et al., 2002).

Family Pelagiellidae Knight, 1956
Genus *Pelagiella* Matthew, 1895

Type species.—*Cyrtolites atlantoides* Matthew, 1894, from the Hanford Brook Formation, Cambrian Series 2–3, New Brunswick, Canada.

Occurrence.—*Pelagiella* has a world-wide distribution, mainly in strata of Cambrian Series 2 and 3. More than 30 species have been proposed, largely on the basis of internal molds (Parkhaev, 2001; Wotte and Sundberg, 2017; Claybourn et al., 2019; Li et al., 2019a). Laurentian records (Fig. 2.1) include Svalbard (Major and Winsnes, 1955), the Browns Pond Formation of New York (Landing and Bartowski, 1996), Ville-Guay, Québec (Landing et al., 2002), North-East Greenland (Skovsted, 2004), the Forteau Formation of western Newfoundland, (Skovsted and Peel, 2007), the Kinzers Formation, Pennsylvania (Skovsted and Peel, 2010; Thomas et al., 2020), Nevada and California (Skovsted, 2006b; Wotte and Sundberg, 2017), and Mexico (Devaere et al., 2019), to which is now added the Aftenstjernesø Formation of North Greenland.

Pelagiella sp.
Figure 7.12

Occurrence.—Aftenstjernesø Formation, North Greenland, Cambrian Series 2, Stage 4.

Materials.—PMU 36912 and two additional specimens from GGU sample 315045.

Remarks.—Only rare internal molds are known from Navarana Fjord, but Skovsted (2004) commented that similar well-preserved specimens are the dominant mollusk in the Bastion Formation of North-East Greenland. *Pelagiella* internal molds are widely distributed and abundant also in undescribed collections from the Aftenstjernesø Formation elsewhere in North Greenland.

Order and family uncertain
Genus *Emargimantus* Skovsted, Brock, and Topper, 2012

Type species.—*Emargimantus angulatus* Skovsted, Brock, and Topper, 2012 from the Ajax Limestone, Cambrian Stage 3, South Australia.

Emargimantus tunuensis (Peel and Skovsted, 2005)
Figure 4.5, 4.6

2005	*Ocruranus tunuensis* Peel and Skovsted, p. 463, fig. 3.
2012	*Emargimantus tunuensis*; Skovsted, Brock, and Topper, p. 258.

Holotype.—MGUH 27222 from GGU sample 314835, upper Bastion Formation, Albert Heim Bjerge, North-East Greenland (Peel and Skovsted, 2005, fig. 3A–D).

Occurrence.—Bastion Formation of North-East Greenland, Aftenstjernesø Formation of North Greenland, Cambrian Series 2, Stage 4.

Materials.—PMU 36886 from GGU sample 315028.

Remarks.—This encrusted single specimen from Navarana Fjord compares well in terms of shape with the holotype from the upper Bastion Formation of North-East Greenland (Peel and Skovsted, 2005, fig. 3A–D). Growth ornamentation is obscure in the North Greenland specimen and the prominent radial cord is less sharply delimited (Fig. 4.6, arrows). Internal molds assigned to *Emargimantus tunuensis* by Peel and Skovsted (2005) display a dense pattern of spines, mainly on the supra-apical surface, similar to *Asperconella* Landing in Landing and Bartowski, 1996, but this surface is not visible in the current specimen.

Emargimantus angulatus Skovsted, Brock, and Topper, 2012 from the Ajax Limestone (Cambrian Stage 3) of South Australia, differs from *Emargimantus tunuensis* by its radially folded sub-apical surface. The median area is formed by a triangular raised area, slightly concave medially, and passes laterally into broad, shallow, radial concavities that terminate at the prominent radiating lateral cords. This surface is uniformly convex in *Emargimantus tunuensis*.

Class Bivalvia Linnaeus, 1758
Family Fordillidae Pojeta, 1975
Genus *Pojetaia* Jell, 1980

Type species.—*Pojetaia runnegari* Jell, 1980 '*Salterella* Limestone,' near Ardrossan, South Australia. This likely corresponds to the Parara Limestone at Horse Gully, near Ardrossan, South Australia (Jell, 1980, p. 234; Bengtson et al., 1990, fig. 4), Cambrian Series 2.

Pojetaia runnegari Jell, 1980
Figure 9.14–9.18

1980 *Pojetaia runnegari* Jell, p. 234, figs. 1A–F, 2A–I, 3C–K.
2009 *Pojetaia runnegari*; Elicki and Gürsu, p. 281, pl. 1, pl. 2, figs. E–H.
2019 *Pojetaia runnegari*; Claybourn et al., p. 443, fig. 3.

Holotype.—National Museum of Victoria specimen number P59669, *Salterella* limestone, South Australia (Jell, 1980, fig. 2A, B).

Occurrence.—Detailed synonymies of *Pojetaia runnegari* Jell, 1980 were given by Elicki and Gürsu (2009) and Claybourn et al. (2019). Elicki and Gürsu (2009) noted records of *Pojetaia runnegari* from Cambrian Series 2–3 of Australia, Germany, China, Transbaikalia, Mongolia, North-East Greenland, and Turkey. Skovsted and Peel (2007) reported specimens from the Forteau Formation of western Newfoundland, while Claybourn et al. (2019) described material from Antarctica. To these is added the current record from the Aftenstjernesø Formation of North Greenland.

Materials.—PMU 36934–PMU 36936 and more than 50 additional internal molds of specimens with conjoined valves from GGU sample 315045.

Remarks.—*Pojetaia runnegari* is the most common mollusk in GGU sample 315045 and the internal molds of the conjoined valves compare well with Turkish material from the Çal Tepe Formation illustrated by Elicki and Gürsu (2009). Internal molds often display prismatic imprints (Fig. 9.18) of the type reported by Runnegar (1985) and described in detail by Vendrasco et al. (2011a).

Biostratigraphy and faunal comparisons

The nevadiid trilobite *Buenellus* Blaker, 1988, from the Sirius Passet Lagerstätte (Montezuman Stage) on the northern coast (Fig. 1.1, 1.5; Blaker and Peel, 1997; Peel and Willman, 2018) is the oldest trilobite known from Greenland, and was also recorded from the Iapetan margin of Laurentia in Tennessee (Webster and Hageman, 2018). *Buenellus* is not known from the Buen Formation in southern outcrops of Peary Land, but nevadiid and olenellid trilobites occurring together in the middle of the Buen Formation (Buen Assemblage 1 of Peel and Willman, 2018) were referred by Hollingsworth (2011) to the late Montezuman Stage. Immediately overlying olenellid-bearing strata (Buen Assemblages 2–4 of Peel and Willman, 2018)

that underlie the Aftenstjernesø Formation were attributed to the Dyeran Stage (Peel and Willman, 2018). The boundary between these two North American stages has been equated with the boundary between Cambrian Stages 3 and 4 of the international standard, but Geyer (2019) reviewed difficulties associated with this correlation, with the Montezuman-Dyeran boundary now placed low in Stage 3 (Sundberg et al., 2020).

The boundary between the Dyeran Stage and the overlying Delamaran Stage was drawn by McCollum and Sundberg (2007) immediately above the extinction of olenellid trilobites. Recent establishment of the base of the Miaolingian Series and the Wuliuan Stage at the base of the *Oryctocephalus indicus* Zone (Zhao et al., 2019) placed the basal Delamaran *Eokochaspis nodosa* and *Amecephalus arrojosensis* zones within Stage 4. In North Greenland, this Cambrian Series 2–Miaolingian boundary lies in the upper Henson Gletscher Formation in southern Peary Land (Geyer and Peel, 2011; Fig. 1.4).

The presence of olenellid trilobites below, within, and above the Aftenstjernesø Formation (Blaker and Peel, 1997; Geyer and Peel, 2011; Peel and Willman, 2018) confirms its assignment to the Dyeran Stage (the traditional *Bonnia-Olenellus* Zone of North American usage).

Sundberg et al. (2016) tentatively recognized three zones within the Dyeran of North Greenland, but seem not to have considered the fauna of the Buen Formation. A basal *Serrodiscus speciosus* Zone was followed after an unresolved interval by an *Eoagnostus roddyi-Oryctocarella duyunensis* Zone and a *Bonnia-Pagetides elegans* Zone. *Serrodiscus speciosus* (Ford, 1873) occurs abundantly in the Aftenstjernesø Formation of northern Nyeboe Land (Fig. 1.3; Blaker and Peel, 1997), but is only tentatively identified as meraspids at the base of the formation (Fig. 5.1–5.6) at Navarana Fjord. *Serrodiscus* species occur throughout the Buen Formation, except at Sirius Passet (Peel and Willman, 2018), but are not known from the overlying Henson Gletscher Formation. *Eoagnostus roddyi* (Resser and Howell, 1938) and *Oryctocarella duyunensis* (Qian, 1961), the latter synonymous with *Arthricocephalus* cf. *A. chauveaui* of Geyer and Peel (2011; the *Oryctocarella duyunensis* of Peng et al., 2017; Geyer 2019), first appear in the middle Henson Gletscher Formation in southern Peary Land such that the zonal status of strata from the upper Aftenstjernesø and lower Henson Gletscher Formation in this area is unresolved.

The Buen Formation (Cambrian Stages 3–4), underlying the Aftenstjernesø Formation (Fig. 1.4), yields a rich biota dominated by trilobites and hyoliths in southern Peary Land (Peel and Willman, 2018), but the lack of carbonates precludes sampling for small shelly fossils that might be compared to the Navarana Fjord assemblages. Digestion of Buen mudstones in hydrofluoric acid has yielded abundant small carbonaceous fossils (Slater et al., 2018; Wallet et al., 2020), but these show little similarity with the carbonate-derived small shelly fossils of the basal Aftenstjernesø Formation.

Small shelly fossils of Cambrian Series 2 age occur world wide, and there is a substantial literature, much of which is cited herein. Many taxa, for example within Mollusca (Claybourn et al., 2019; Li et al., 2019a; Parkhaev, 2019), are reported from several continents and paleocontinents. Similarities between the extensive faunas of the upper Bastion Formation of North-East Greenland and occurrences in Australia, Siberia,

and Antarctica discussed by Skovsted (2006a) are confirmed, although the present discussion focuses on Laurentia (Fig. 2.1). However, as noted by Landing and Bartowski (1996), many small shelly fossils from eastern North America have long stratigraphic ranges in the middle and late Dyeran.

The fauna from Navarana Fjord accumulated on the currently southern side of the transarctic Franklinian Basin on the Innuitian margin of Laurentia, influenced by Ellesmerian orogenesis (Trettin, 1991; Higgins et al., 1991a, b; Dewing and Nowlan, 2012). While equivalent small shelly faunas are known as far west as easternmost Ellesmere Island, Nunavut (Peel and Skovsted, in press; Fig. 2.4), they have not been described through the Canadian Arctic Islands (Fig. 2.1). Most described equivalent faunas occur along the Iapetan Margin of Laurentia, which was influenced by Caledonide orogenesis, currently the eastern coast of North America from North-East Greenland to Pennsylvania (Fig. 2.6–2.10). It is questionable, however, given the strong similarity between the faunas of Navarana Fjord and North-East Greenland (Skovsted, 2006a), if this distinction had any significant effect on faunal distribution in these northern areas during the Cambrian.

Svalbard.—North Greenland preserves the present day northernmost Cambrian in Laurentia, but the easternmost outcrops lie on the archipelago of Svalbard, ~600 km to the east of North Greenland, at ~76–80°N, 11–28°E (Gee and Teben'kov, 2004; Figs. 1.2, 2.1). The islands have a complex structural history, but fossiliferous lower Cambrian (Cambrian Series 2) strata in the southwest (Fig. 2.1, locality 2) yield trilobite faunas with *Serrodiscus* and olenellids, comparable to North Greenland (Major and Winsnes, 1955; Birkenmajer and Orlowski, 1977; Blaker and Peel, 1997; Peel and Willman, 2018). The succession in the northeast (Fig. 2.1, locality 3) compares closely with North-East Greenland (Harland, 1997; Stouge et al., 2011). From this latter area, *Salterella* Billings, 1861 was described by Lauritzen and Yochelson (1982), Knoll and Swett (1987), Dunkley Jones (2007), and Stouge et al. (2011). It is widely distributed in Greenland (Peel and Yochelson, 1982; Peel, 2017b), but has not been recognized in the outer shelf setting at Navarana Fjord.

Wrona (1982) described the palaeoscolecidan sclerite *Hadimopanella apicata* from southwest Svalbard (Fig. 2.1, locality 2). While not reported herein from the relatively coarse-sieve fractions of the residues available from Navarana Fjord, *Hadimopanella apicata* occurs widely in fine-sieve fractions from the Aftenstjernesø Formation in northern Nyeboe Land, southern Lauge Koch Land, and Peary Land, in the Kap Troedsson Formation of southern Wulff Land, and in the Henson Gletscher Formation of southern Freuchen Land (Fig. 1.3; Peel and Larsen, 1984; Bendix-Almgren and Peel, 1988; Peel, 2017b). Other records of *Hadimopanella apicata* include North-East Greenland (Fig. 2.1, locality 6; Skovsted, 2006a), Antarctica (Wrona, 2004), and Australia (Topper et al., 2010).

Southern Freuchen Land to southern Peary Land.—The fauna of the basal Aftenstjernesø Formation at the type section in southern Lauge Koch Land (Fig. 1.1, locality D) is not yet described, but it includes the great majority of taxa described herein from Navarana Fjord. Notable differences include common tubes of *Hyolithellus*, spines of *Mongolitubulus henrikseni* Skovsted and Peel (2001), and a greater diversity of helcionelloid internal molds in the south. *Eiffelia*, *Chancelloria*, and *Archiasterella* are also more common in the south, but some of these differences may reflect sample size. Similar faunas are known also from the basal Aftenstjernesø Formation in outcrops across southern Peary Land to southern Freuchen Land (Fig. 1.3). The bivalve *Fordilla* Barrande, 1881 may be locally common in southern Peary Land, but is not present at Navarana Fjord. Published records include Peel et al. (1974), Runnegar and Pojeta, (1992), Atkins and Peel (2004, 2008), Vendrasco et al. (2011a), and Peel (2019a, b).

Rich macrofaunas and small carbonaceous fossils of Stage 4 occur also in the siliciclastic sediments of the underlying Buen Formation in these southern outcrops (Blaker and Peel, 1997; Peel and Willman, 2018; Slater et al., 2018). Overlying carbonates and mudstones of the Henson Gletscher Formation preserve diverse late Stage 4 faunas (Blaker and Peel, 1997; Geyer and Peel, 2011; Peel et al., 2016) not recognized in northern outcrops.

Southern Wulff Land.—The Kap Troedsson Formation (Cambrian Stage 4) of southern Wulff Land (Fig. 1.3) grades to the northeast into the equivalent lower member of the Aftenstjernesø Formation (Ineson and Peel, 1997). The carbonate ramp succession of the Kap Troedsson Formation is dominated by gray, thin-bedded, silty, skeletal grainstones, packstones, and lime mudstones with phosphatized hardgrounds (Ineson and Peel, 1997; Peel, 2014a, 2017a, b, c).

The Kap Troedsson Formation is richly fossiliferous and differences in fauna with the Navarana Fjord assemblage likely represent its shallower water setting. Trilobites from the Kap Troedsson Formation include *Calodiscus* (Howell, 1935), *Ekwipagetia*, *Olenellus* Hall, 1861, *Labradoria misera*? (Billings, 1861), and *Kootenia* Walcott, 1889 (Blaker and Peel, 1997). *Ekwipagetia* occurs together with *Serrodiscus* at Navarana Fjord, but *Calodiscus* is not reported; conversely, *Serrodiscus* is not present in the Kap Troedsson Formation. *Botsfordia* and *Eoobolus priscus* are rare at Navarana Fjord, but may be abundant in the Kap Troedsson Formation (Peel, 2014a). *Chancelloria*, *Pelagiella*, *Pojetaia*, *Eifffelia*, *Davidonia*, *Triplicatella*, and edrioasteroid plates are present in both. Hyolith conchs are common in the Kap Troedsson Formation, but opercula dominate at Navarana Fjord. The bradoriids *Beyrichona avanga* Peel, 2017c and *Hipponicharion skovstedi* Peel, 2017c are common in the Kap Troedsson Formation (Peel, 2017c), but absent in northern Lauge Koch Land. However, *Spinospitella* is present in northern Lauge Koch Land, but absent from the Kap Troedsson Formation. *Discinella micans* (Billings, 1871), *Microdictyon* Bengtson, Matthews, and Missarzhevsky in Missarzhevsky and Mambetov, 1981, *Mongolitubulus henrikseni*, *Salterella*, and *Hadimopanella* are common in the Kap Troedsson Formation, but not recorded from Navarana Fjord.

Northern Nyeboe Land and Nunavut.—Faunas from the Aftenstjernesø Formation in northern Nyeboe Land (Figs. 1.3, 2.1, locality 4) were reported by Peel (1974) and Dawes and Peel (1984), with trilobite assemblages dominated by species of *Serrodiscus* described by Blaker and Peel (1997), including

Serrodiscus daedalus, which otherwise is known from Australia (Öpik, 1975). Small shelly fossils are similar to those known from Navarana Fjord (Peel and Larsen, 1984; Peel, 2014b; Peel and Skovsted, in press), but are largely undescribed.

A similar fauna was reported from the Kennedy Channel Formation on Judge Daly Promontory, Ellesmere Island, Nunavut (Fig. 2.1, locality 4) by Long (1989), but Dewing et al. (2004) demonstrated subsequently that the fossiliferous strata were tectonically emplaced within the Proterozoic(?) Kennedy Channel Formation from the overlying Ellesmere Group. The Judge Daly fauna collected by Long (1989) is dominated by *Pojetaia* and chancelloriid rays, with *Pelagiella*, *Hyolithellus*, *Cupitheca*, and fragmentary linguliformean brachiopods (Peel and Skovsted, in press), most of which are present at Navarana Fjord and indicate a Cambrian Stage 4 age. This appears to be the same fauna as that reported by Nowlan (2001).

Inglefield Land.—The Laurentian inner shelf carbonate succession in Inglefield Land (Figs. 1.3, 2.1, locality 5) is one of the classic areas of Cambrian paleontology in North America, with diverse macrofossil assemblages described by Poulsen (1927, 1958, 1964), Palmer and Peel (1981), and Peel (2020a, b), but it has not been sampled for small shelly fossils. Equivalent strata in southern Daugaard-Jensen Land (Fig. 1.3), recovered from the transition from transgressive siliciclastic sediments of the Humboldt Formation (equivalent to the Buen Formation, Fig. 1.4) to the overlying inner carbonate shelf succession, contains internal molds of *Chancelloria*, *Hyolithellus*, *Pelagiella*, and hyoliths (Peel and Skovsted, in press), and olenellid fragments, indicating a Dyeran age similar to that of the Aftenstjernesø Formation (Cambrian Stage 4). The bradoriid *Beyrichona* is conspicuous, as are small colonial archeocyaths and fragments of *Setatella* Skovsted et al., 2010, but they are not recorded at Navarana Fjord. Conversely, the widely distributed stem-group bivalve *Pojetaia runnegari* and the stem-group aculiferans *Hippopharangites* and *Qaleruaqia* are not present in Daugaard-Jensen Land.

North-East Greenland.—Following the usage of Grønlands Geologiske Undersøgelse (Geological Survey of Greenland) since 1976, Cambrian strata described by Skovsted (2006a) and subsequent authors (e.g., Jensen et al., 2016) are located to North-East Greenland (Figs. 1.2, 2.1, locality 6). North-East Greenland encompasses the area from Kong Oscars Fjord (72° N) in the south to Nioghalvfjerdsfjorden in the north (79° 30′N). Watt (2019) restricted North-East Greenland to areas north of Kuhn Ø (75°N), introducing a new descriptor, northern East Greenland, for the area 72°N–75°N, but this is not followed (Fig. 2.1, locality 6).

The most diverse small shelly fossil assemblages in Greenland, and likely throughout Laurentia, were described from the Bastion and Ella Island formations of North-East Greenland (Fig. 2.1, locality 6) by Skovsted (2006a), with detailed studies of individual groups by Skovsted and Peel (2001), Skovsted (2003, 2004), Skovsted and Holmer (2003, 2006), Gubanov et al. (2004), Malinky and Skovsted (2004), Skovsted et al. (2004, 2010), Peel and Skovsted (2005), and Skovsted and Topper (2018). The fauna includes more than 90 species—almost

twice the number described here from northern Lauge Koch Land—but it is based on more than 50 samples. Notwithstanding these differences, the faunas are similar in diversity and composition, with almost all taxa from Navarana Fjord represented in North-East Greenland. However, specimens of linguliformean brachiopods and mollusks are much more numerous in North-East Greenland. *Mongolitubulus henrikseni*, *Salterella*, and *Discinella* are abundant in North-East Greenland, but absent in the samples from Navarana Fjord, although present in the Kap Troedsson Formation of southern Wulff Land. As is also the case with the latter formation, the fauna from Navarana Fjord likely accumulated in a deeper water setting than North-East Greenland. Skovsted (2006a) proposed a Cambrian Stage 4 (Dyeran, Botoman) age for the faunas of the upper Bastion and Ella Island formations, but Watt (2019, p. 127) erroneously stated Tommotian–Atdabanian (Cambrian Stage 3) as the age of the Bastion Formation on the basis of trace fossils described by Pickerill and Peel (1990) from just the lower beds.

Western Newfoundland.—The fauna of small shelly fossils described by Skovsted et al. (2004, 2017) and Skovsted and Peel (2007) from the Forteau Formation (Stage 4) of western Newfoundland (Fig. 2.1, locality 7) shows similarities to Navarana Fjord, not least among the mollusks and hyolith opercula. The occurrence of *Cassitella baculata*, otherwise known from North and North-East Greenland, is noteworthy, but the distinctive operculum here assigned to *Neogloborilus* was also recorded by Skovsted and Peel (2007). *Triplicatella peltata*, reported from the Forteau Formation, is not recorded at Navarana Fjord, but its holotype is derived from the basal Aftenstjernesø Formation of western Peary Land (Skovsted et al., 2004). The brachiopod assemblage described by Skovsted et al. (2017) from the Forteau Formation is much more diverse than that described herein from Navarana Fjord, where brachiopods are infrequent, but *Botsfordia*, *Eoobolus priscus*, and *Obolella crassa* are present in both.

Skovsted et al. (2017) noted that *Eoobolus priscus* was characteristic of outer shelf deposits in the Forteau Formation, whereas *Botsfordia caelata* (Walcott, 1912) occurred in higher energy, transgressive, inner shelf deposits. Rare specimens of each occur together in GGU sample 315045 from Navarana Fjord.

Ville-Guay, Québec.—Trilobites indicate that the *Bicella bicensis* microfauna from the "Anse Maranda Formation" of Ville-Guay, Québec (Landing et al., 2002; Fig. 2.1, locality 8) is a correlative of latest Stage 4 faunas in North Greenland preserved in the upper Henson Gletscher Formation of western Peary Land (Geyer and Peel, 2011; Peel et al., 2016), and therefore younger than the Aftenstjernesø Formation at Navarana Fjord and elsewhere in the southern Peary Land area. Much of the non-trilobitic fauna from Ville-Guay is similar to the that of older Browns Pond Formation of New York (Landing and Bartowski, 1996), but few of these particular species are present at Navarana Fjord.

Taconic sequence of New York.—The fauna of the Browns Pond Formation of the Taconic allochthon of New York State (Landing and Bartowski, 1996; Fig. 2.1, locality 9) is similar

in composition to that of the Aftenstjernesø Formation at Navarana Fjord, in part reflecting their common deposition in slope environments. The formation is assigned to the *Elliptocephala asaphoides* Zone of the Dyeran and is likely of the same age as the lower Aftenstjernesø Formation in North Greenland (Landing and Bartowski, 1996; Sundberg et al., 2016). The Browns Pond Formation shares *Davidonia*, *Pelagiella*, *Yochelcionella*, *Conotheca laurentiensis*, and possibly *Hippopharangites groenlandicus* n. sp. with the Navarana Fjord samples. Similar edrioasteroid plates also occur in both. Olenellids and *Calodiscus* present in the Browns Pond Formation are not recorded at Navarana Fjord, but do occur in the Aftenstjernesø Formation in southern Peary Land. Conversely, Landing and Bartowski (1996) did not record *Serrodiscus* or *Ekwipagetia* in their samples from the Browns Pond Formation, but both were described from New York State by Rasetti (1967). The distinctive helcionellid mollusk *Asperconella*, originally described from the Browns Pond Formation by Landing and Bartowski (1996), is widespread in more southern outcrops of the Aftenstjernesø Formation, but is not known from Navarana Fjord.

Pennsylvania.—Small shelly fossils from the Kinzers Formation (Cambrian Stage 4) at Thomasville (Fig. 2.1, locality 10) were described by Runnegar and Pojeta (1980), Atkins and Peel (2008), Skovsted and Peel (2010), and Thomas et al. (2020). Skovsted et al. (2017) commented on the similarity with the Forteau Formation. *Chancelloria*, *Conotheca*, *Yochelcionella*, *Pelagiella*, and *Eoobolus priscus* also occur at Navarana Fjord, but *Salterella* is absent.

Western Canada.—Small shelly fossil assemblages described from the Yukon Territory (Fig. 2.1, locality 11) and Northwest Territories (Fig. 2.1, locality 12) by Nowlan et al. (1985), Voronova et al. (1987), and Pyle et al. (2006) were derived from strata of Terreneuvian age and therefore older than the Cambrian Series 2 (Stage 4) faunas from Navarana Fjord. Assemblages of exceptionally preserved small carbonaceous fossils have been described from the Mount Cap Formation (Cambrian Series 2–3), Northwest Territories (Butterfield, 1994; Harvey and Butterfield, 2011; Fig. 2.1, locality 12), but cannot be compared closely to the fauna of the Aftenstjernsø Formation, as is the case also with material from the Buen Formation of southern Peary Land described by Slater et al. (2018) and Wallet et al. (2020).

Skovsted et al (2020) described early Cambrian faunas (Stage 3–4) from the Mural Formation of southwestern Canada (Fig. 2.1, locality 13), but only *Hyolithellus* is shared with the assemblage from Navarana Fjord.

Western USA.—Small shelly fossils from the Great Basin (Fig. 2.1, locality 14) were described by Skovsted (2006b), Skovsted and Holmer (2006), and Wotte and Sundberg (2017). The fauna from the basal Emigrant Formation at Split Mountain, Nevada, described by Skovsted (2006b), is late Dyeran (Cambrian Stage 4) in age and thus correlative with faunas described from the upper Henson Gletscher Formation in North Greenland (Geyer and Peel, 2011; Peel et al., 2016) rather than with the underlying Aftenstjernesø Formation. *Anabarella* and

Parkula occur at Split Mountain and at Navarana Fjord, but are represented by different species. In both cases they are associated with *Chancelloria*, pelagiellids, echinoderm plates, and a slender hexactine sponge spicule. Wotte and Sundberg (2017) also described small Montezuman (Cambrian Stage 3) faunas from the Campito and Poleta formations, but these do not compare closely with Navarana Fjord.

Skovsted and Holmer (2006) described a Dyeran fauna from the Harkless Formation of Nevada, but this shows little similarity with Navarana Fjord. Trilobites described by Palmer (1964) from the upper part of the formation indicate equivalence with the Henson Gletscher Formation (Blaker and Peel, 1997; Geyer and Peel, 2011; Sundberg et al., 2016).

Sonora, Mexico.—Devaere et al. (2019) described Cambrian Stage 3–4 small shelly faunas from the Puerto Blanco Formation of Sonora, Mexico (Fig. 2.1, locality 15). Material compared to *Archiasterella pentactina* occurs throughout the Puerto Blanco Formation and in the Aftenstjernesø Formation of Navarana Fjord. *Chancelloria*, *Davidonia*, *Parkula bounites*, *Cupitheca*, *Pelagiella*, and *Pojetaia* occur in both faunas, but closer species comparisons were not made. Devaere et al. (2019) assigned most of the Puerto Blanco fossils to Cambrian Stage 3, while the present fauna from Navarana Fjord is Stage 4. Fossils of Stage 3 age in North Greenland are known only from siliciclastic sediments of the Buen Formation (Peel and Willman, 2018).

Acknowledgments

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