# Lower Ordovician trilobites from the Baumann Fiord Formation, Ellesmere Island, Arctic Canada

# Jonathan M. Adrain and Stephen R. Westrop

Abstract: Sections through member B of the Baumann Fiord Formation on the Bache Peninsula, Ellesmere Island, Arctic Canada, contain a range of lithofacies indicating deposition in shallow subtidal settings above storm wave base. Macrofossils are generally rare, but low-diversity trilobite-dominated faunas occur in a section near Sanddöla Creek. The only other fossils common in the collections are poorly preserved gastropods. All of the trilobite species are apparently new, and four are formally named: *Licnocephala sanddoelaensis*, *"Peltabellia" baumannensis*, *Bolbocephalus ellesmerensis*, and *Ceratopeltis bachensis*. The species *Ceratopeltis forteyi* is introduced for material previously described from North Greenland. Rare additional species of *Licnocephala* and *Jeffersonia* are reported in open nomenclature. The trilobites occur in three stratigraphically and lithologically distinct associations, with species diversity ranging from two to four. Closest comparisons of the trilobite species all indicate that member B should be assigned to the Tulean Stage of the Ibexian Series. *Rananasus* Cullison, 1944, is placed in synonymy of *Bolbocephalus* Whitfield, 1890.

**Résumé :** Des coupes dans le membre B de la formation de Baumann Fiord, dans la péninsule Bache de l'île d'Ellesmere, dans l'Arctique canadien, présentent divers lithofaciès qui témoignent de milieux de dépôt infralittoraux peu profonds situés au-dessus de la zone d'action des vagues de tempête. Les macrofossiles y sont généralement rares, mais des assemblages fauniques de faible diversité dominés par des trilobites sont présents dans une coupe exposée à proximité du ruisseau Sanddöla. Les seuls autres fossiles répandus dans ces collections sont des gastéropodes en mauvais état de conservation. Toutes les espèces de trilobites qui s'y trouvent sont vraisemblablement nouvelles, et des noms formels ont été assignés à quatre de celles-ci, soit *Licnocephala sanddoelaensis*, *« Peltabellia » baumannensis*, *Bolbocephalus ellesmerensis* et *Ceratopeltis bachensis*. L'espèce *Ceratopeltis fortey* est introduite pour du matériel décrit antérieurement provenant du nord du Groenland. D'autres rares espèces de *Licnocephala* et *Jeffersonia* sont également signalées en nomenclature ouverte. Les trilobites se présentent dans trois associations distinctes sur les plans stratigraphique et lithologique, comptant chacune de deux à quatre espèces. La comparaison des espèces de trilobites aux assemblages d'autres régions indique que le membre B de la formation de Baumann Fiord devrait être affecté au stade tuléen de l'Ibexien. *Rananasus* Cullison, 1944, est placé en relation de synonymie avec *Bolbocephalus* Whitfield, 1890.

[Traduit par la Rédaction]

## Introduction

The Lower Ordovician Baumann Fiord Formation is a shallow-water unit developed on the Arctic Platform across the southern and eastern Canadian Arctic Archipelago (Kerr 1967, 1968, 1974; Thorsteinsson and Kerr 1968; McGill 1974; Morrow and Kerr 1977; Mayr 1978, 1980; Mossop 1979; Mayr and de Freitas 1992; Turner and Mayr 1999). The formation is represented in northern Greenland as the Poulsen Cliff and Nygaard Bay formations (see Peel and Christie 1982) and was studied in detail across central

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**J.M. Adrain.**<sup>1</sup> Department of Geoscience, University of Iowa, Iowa City, IA 52242, USA.

**S.R. Westrop.** Oklahoma Museum of Natural History and School of Geology and Geophysics, University of Oklahoma, Norman, OK 73072, USA.

<sup>1</sup>Corresponding author (e-mail: jonathan-adrain@uiowa.edu).

Ellesmere Island by Mossop (1979). Here, we describe the trilobite fauna and sedimentology of the middle part (member B) of the formation at two localities on the Bache Peninsula, east-central Ellesmere Island (Fig. 1).

Lower Ordovician (Ibexian) trilobite faunas have been documented from northern Greenland (Poulsen 1927, 1937; Fortey 1986; Fortey 1979, 1989, 1990), but Poulsen (1946) is the only substantial publication to date on those of Arctic Canada. Shallow-water faunas similar to those from Greenland have been described from western Newfoundland (Fortey and Peel 1983; Boyce 1989) and from the Laurentian Hebridean Terrane in Scotland (Fortey 1992). The faunas from member B of the Baumann Fiord Formation are not precisely age equivalent to any previously described from the northern and eastern Laurentian regions, and all of the species present are apparently new.

## Stratigraphic setting

The Baumann Fiord Formation (Kerr 1967) is part of a thick Cambrian–Devonian package deposited on the Arctic Platform, a region in the southern and eastern Arctic in which the Phanerozoic strata have not been deformed on a



Fig. 1. (a) Position of Bache Peninsula on east-central Ellesmere Island (box, enlarged in b). (b) Position of measured sections at Sanddöla Creek (SCr) and Bartlett Bay (BB).

regional scale (Trettin 1991). During the Late Cambrian -Middle Ordovician, the southeastern portion of the platform appears to have been in the form of a rimmed shelf, rather than a carbonate ramp, with extensive peritidal deposits (Mossop 1979; Trettin et al. 1991). The rim itself is preserved only locally (Trettin et al. 1991, p. 178, fig. 8B.2), and the succession in the study area was deposited in what has been interpreted as an intrashelf basin inboard of the rim. Evaporites are developed locally in the Late Cambrian peritidal successions of the Cass Fjord Formation of eastern Ellesmere Island (Christie 1967; Trettin et al. 1991, p. 175, fig. 8B.12), whereas the Baumann Fiord Formation records a regionally extensive, Early Ordovician episode of evaporite deposition that extended across Ellesmere, Bathurst, and Cornwallis islands. The evaporites can also be traced eastward across the Kane Basin into Washington Land, northwestern Greenland, where they are assigned to the Poulsen Cliff and Nygaard Bay formations (Peel and Christie 1982; Higgins et al. 1991).

The Baumann Fiord Formation is divided into three informal members, in ascending order, members A, B, and C (Kerr 1968) (Figs. 3a, 3b). Members A and C are composed of metre-scale, carbonate-evaporite cycles (Mossop 1979, fig. 10), whereas member B is composed exclusively of carbonates. Member A accounts for most of the formation and, according to Mossop (1979, Table 2), is 188 m in thickness at Sanddöla Creek, Ellesmere Island; members B and C reach 33 m and 44 m in thickness, respectively, at Sanddöla Creek. In Washington Land, northeastern Greenland, the Poulsen Cliff Formation (100-125 m) consists of interbedded carbonates and evaporites, and the overlying, thinner Nygaard Bay Formation (40 m) is divided into a lower carbonate unit and an upper evaporite-rich interval that are equal in thickness (Peel and Christie 1982; Higgins et al. 1991). Thus, the Poulsen Cliff Formation can be correlated with member A, and the Nygaard Bay Formation is equivalent to members B and C.

Mossop (1979) regarded the evaporite cycles of members A and C as coastal sabkha deposits that formed under supratidal conditions. More recently, Trettin et al. (1991) suggested a subaqeous origin in a broad, shallow, saline basin, and Higgins et al. (1991) favoured a similar interpretation for correlative evaporites of northwestern Greenland. The carbonates of member B were treated briefly by Mossop, who regarded them as having formed in a restricted, shallow, shelf lagoon. Here, we describe the lithofacies of member B in the study area and present an environmental interpretation.

## Study area

Sections were measured on the west and east ends of the Bache Peninsula, central Ellesmere Island, at Sanddöla Creek (SCr) and Bartlett Bay (BB), respectively (Figs. 1, 2). The study site at Sanddöla Creek (Figs. 3a, 3b) lies just to the east of locality 9 of Christie (1967) and section 5 of Mossop (1979, p. 7). The lower contact is not exposed, but the 29 m section through member B (Fig. 2) is nearly complete because Mossop (Table 2) recorded a thickness of 33 m at his section. Trilobites were recovered from float in two thin, talus-covered intervals in the lower half of the member (Fig. 2). The section at Bartlett Bay was measured on the south side of the bay, along the east side of a stream gully that is occupied by the major fault indicated in Christie's map. Only 13 m of member B is exposed at Bartlett Bay (Fig. 2) and, from the presence of thrombolites at the base, this interval probably correlates with the lower half of the section at Sanddöla Creek, about 40 km to the west. No trilobites were recovered, and the section is illustrated to aid understanding of the depositional environments.

# Lithofacies

## Intraclastic rudstone and bio-intraclastic packstone

This lithofacies occurs in units that range from 5 cm to

Fig. 2. Stratigraphic columns of sections at Sanddöla Creek (showing position of collections SCr-L and SCr-U) and Bartlett Bay. The inset shows a generalized stratigraphic column of the Princess Marie Bay region. Camb., Cambrian; M.O., Middle Ordovician.



more than 1 m in thickness, with the latter comprising several amalgamated beds. Rudstones (Fig. 3e, 3f) are typically composed of discoidal pebbles of mostly lime mudstone in a bio-intraclastic matrix; long axes of pebbles are subparallel to bedding. Less commonly, rudstones consist mostly of equant, angular to subrounded pebbles. Bio-intraclastic packstones may include discoidal pebbles, and, in some cases, beds are graded, with pebbles forming a basal lag. Beds are typically tabular sheets, usually with planar bases (Fig. 3c). In rare cases, intraclastic rudstones overlie irregular (centimetre-scale relief), scalloped to overhanging hardgrounds developed on lime mudstone (Fig. 3e).

#### Interpretation

Following earlier work (Braun and Friedman 1969), Mossop (1979, p. 12) interpreted intraclastic rudstones in members A and C as supratidal deposits produced by storm reworking of desiccated lime mud. Intraclastic rudstones composed of clasts of, and interbedded with, microbial laminites (e.g., Mossop 1979, fig. 20C) may well have been deposited in high intertidal and supratidal environments (e.g., see Aigner 1985, p. 64, fig. 31D; Osleger and Read 1991, Table 1; Demicco and Hardie 1994, fig. 32C). Rudstones of member B, however, are not associated with features indicative of subaerial exposure (e.g., desiccation cracks, fenestral fabric), and it is more likely that they are subtidal deposits generated by reworking of lithified layers close to the sediment–water interface (e.g., Sepkoski 1982; Myrow et al. 2004). Biointraclastic packstones differ from the rudstones in the lower proportion of pebbles. Graded beds resemble tempestites illustrated by Aigner (1982, fig. 2C) and, like the rudstones, the packstones may be interpreted as subtidal deposits.

## Thin- to nodular-bedded lime mudstone and calcisiltite

Lime mudstone dominates in thin (centimetre thick) beds separated by shaly partings (millimetre to centimetre);



Fig. 3. Exposures and lithofacies of member B, Baumann Fiord Formation, Sanddöla Creek section (SCr). Measurements (in metres) refer to levels in the stratigraphic column in Fig. 2. (a) View along strike to the east of the section, showing upper and approximate lower (talus covered) boundary of member B (black arrows). Evaporites of member A are largely covered and restricted to a few weathered patches (white arrow). Person (circled) provides scale. (b) View normal to strike, showing upper boundary of member B and overlying member C (largely talus covered). Limestones exposed at top of member B are those which form the upper bench at top of the member in Fig. 1a. Cliff-forming carbonates of the Eleanor River Formation (E.R.) are exposed above talus slope. (c) Interval 13.3-14.2 m above base of the section. Wavy- to nodular-bedded lime mudstone and calcisilitie, with thin (mm) shaly partings. Thicker bed near top of image is an interval of amalgamated intraclastic rudstone and thin (cm) calcisilitie horizons. Pen (arrow) provides scale. (d) Lower portion of the section. Thick unit at base is thrombolitic microbial buildup, 1.65 m above base of section. Arrows emphasize relief along upper surface of buildup. Thicker, resistant beds above buildup are units of bio-intraclastic packstone. Hammer (circled) provides scale. (e) Two beds of intraclastic rudstone separated by thin (centimetre) lime mudstone, 23.75 m above base of the section. Lower bed is composed largely of tabular, discoidal clasts of lime mudstone; upper bed includes more equant, angular to subrounded clasts. Lower intraclastic rudstone overlies irregular, scalloped hardground (arrows) with centimetre-scale relief developed on lime mudstone. The top of the pen provides scale. (f) Intraclastic rudstone overlying wavy-bedded lime mudstone and laminated calcisiltite, 13.2 m above base of the section. Tabular, discoidal clasts are composed largely of lime mudstone. Matrix is sand grade and composed mostly of intraclasts. Scale bar = 1 cm. (g) Pavement of silicified orthid brachiopod valves on upper bedding surface of bioclastic packstone to rudstone, 15.6 m above base of the section. Scale bar = 1 cm. (h) Upper bedding surface of gastropod-rich bioclastic rudstone with rare trilobite sclerites (arrow), 11.5 m above base of the section. Top of pen provides scale.

calcisiltites are plane- or ripple-laminated. Lenses and thin (centimetre) beds of intraclastic rudstone are common. Rare nodular lime mudstone beds contain abundant trilobites and planispiral gastropods on their upper surface, and this facies hosts the *Licnocephala* and *Bolbocephalus* associations described later in the paper.

#### **Interpretation**

Similar facies (Pratt and James 1986, fig. 9C) were interpreted by Pratt and James (1986) as predominantly intertidal. The absence of mudcracks or fenestral fabrics in member B argues against an intertidal origin, however, and the abundant intraclastic rudstones suggest a shallow subtidal setting. There are also similarities with the "intercalated heterolithic thin bed" facies in the El Paso Group of western Texas and southern New Mexico (Goldhammer et al. 1993), which were regarded as indicating shallow subtidal conditions. The absence of some features described by Goldhammer et al. (1993), including bioturbation and a diverse shelly fauna, probably reflects more restricted conditions during the deposition of member B.

#### **Bioclastic rudstone**

Bioclasts are only locally abundant in the carbonates of member B. Brachiopod-rich (Fig. 3g) and gastropod-rich (Fig. 3h) rudstones occur as thin beds and pavements and are also present in the channel fills between the heads of thrombolitic microbial buildups. In all cases, diversity is relatively low. Trilobites occur in association with gastropods (Fig. 3h), but the brachiopod pavements are monospecific assemblages.

### Interpretation

The rudstones are probably storm-generated accumulations. They also indicate relatively high abundances of species in the local environment, however, suggesting that they may reflect opportunistic blooms when salinity approached normal marine levels. The low diversity implies that conditions remained relatively restricted, and even the presence of articulate brachiopods at some horizons need not indicate normal marine conditions. Fürsich and Hurst (1979) argued that some monospecific or low-diversity assemblages of brachiopods in marginal marine environments (including examples from the Lower Ordovician Wandel Valley Formation of northeastern Greenland) may have lived under slightly elevated salinities.

Mossop (1979) suggested periodic freshwater influx might have lowered salinities in restricted, hypersaline, nearshore lagoons sufficiently to allow immigration of the fauna. This interpretation was based on the presence of red marls that Mossop regarded as freshwater deposits. Such marls are not present in the sections that we studied, and an influx of normal marine waters due to relative sea level rise is an equally plausible alternative.

### **Microbial carbonates**

Microbial carbonates are represented by three distinct lithofacies. Patch reefs of laterally coalesced, thrombolitic microbial boundstone with up to 15 cm of relief on the upper bedding surface (Fig. 3f) occur in the lower half of the member. Planar microbial laminites, similar to those described by Mossop (1979) from members A and C, are confined to the uppermost portion of member B at Sanddöla Creek. They are associated with and may pass laterally into low (decimetre-scale) domal (LLH) stromatolitic mounds.

#### **Interpretation**

Thrombolites have been described from a variety of Cambrian and Early Ordovician successions and have generally been interpreted as shallow subtidal in origin (e.g., Pratt and James 1986; Westrop 1989; Osleger and Read 1991). From the distribution of modern hardened stromatolites (e.g., Dravis 1983), Goldhammer et al. (1993) suggested a depth range of 5–10 m for Lower Ordovician sponge–thrombolite mounds of west Texas. Planar microbial laminites likely record deposition in high intertidal to supratidal settings (e.g., Pratt and James 1986; Koerschner and Read 1991; Pratt et al. 1992). Domal stromatolitic mounds are associated with the planar laminites (Fig. 2) and must also have formed under peritidal conditions.

## Parallel-laminated dolostone

This lithofacies is similar to the "laminar limestone" illus-

**Fig. 4.** Pie diagrams of trilobite associations from member B of the Baumann Fiord Formation at Sanddöla Creek, Bache Peninsula, Ellesmere Island. Numbers given are summed counts of all sclerites. (*a*) *Licnocephala* association from SCr-L. *Licnocephala sanddoelaensis* = 57; "P." *baumannensis* = 11; *Licnocephala* n.sp. A = 3. (*b*) *Ceratopeltis* association from SCr-U. *Ceratopeltis bachensis* = 71; "P." *baumannensis* = 10; *Jeffersonia* sp. = 2; *L. sanddoelaensis* = 1. (*c*) *Bolbocephalus* association from SCr-U. *Bolbocephalus* = 8; *L. sanddoelaensis* = 3.



trated by Mossop (1979). The subparallel lamination contrasts with the irregular lamination of the planar microbial laminites that overlie the parallel-laminated dolostone in the upper part of the Sanddöla Creek section. At Bartlett Bay, the parallel-laminated lithofacies passes laterally into domal (LLH) stromatolites.

### Interpretation

Parallel-laminated dolostones have been described by Grimwood et al. (1999) from the Black River Group of southern Ontario and were regarded as intertidal to supratidal deposits; Goldhammer et al. (1993) offered a similar interpretation for planar laminites in the Lower Ordovician of west Texas. The association with planar microbial laminites and LLH domal stromatolites of lithofacies 4 in member B supports a peritidal origin. Mossop (1979) interpreted laminar lime mudstone as recording a subtidal, lagoonal environment within upward-shallowing sabkha cycles of members A and C. As this lithofacies grades up into microbial laminites in the cycles (Mossop 1979, p. 13, fig. 10), however, an origin within the intertidal zone cannot be ruled out in members A and C.

#### Conclusions

Most of member B was deposited under shallow subtidal conditions above storm wave base, with only the upper few metres representing intertidal to supratidal environments. The low-diversity faunas that are restricted to a few horizons suggest that salinities were usually elevated above normal marine levels. Thus, regardless of the origin of evaporites of members A and C, the nearshore, lagoonal setting suggested by Mossop (1979) for member B seems to be a reasonable interpretation.

## **Trilobite associations**

All of the trilobite collections are from talus, but the trilobite-yielding interval is only about 5 m thick, and the collected blocks were essentially weathering in place; their provenance is not in doubt. Collections were made from two ledges in the interval, a lower one designated SCr-L hereafter, and an upper one designated SCr-U. A single trilobite association characterizes the SCr-L sample, whereas two very different associations occur in separate lithologies in the

SCr-U sample. Three trilobite associations can hence be recognized as follows.

#### Licnocephala association

All of the samples from SCr-L occur as fairly densely crowded (e.g., Fig. 7t) sclerites on the upper bedding surface of nodular lime mudstones (lithofacies as described in the section titled Thin- to nodular-bedded lime mudstone and calcisilitie). The mudstones are 1–5 cm thick and lack obvious fossils except on their upper surface. Trilobites are numerically dominant, but poorly preserved (rapidly weathering through) large planispiral gastropods are also common. This trilobite association includes three species and is strongly dominated by *Licnocephala sanddoelaensis* (Fig. 4*a*), with less common *Peltabellia baumannensis* and very rare *Licnocephala* n.sp. A.

#### Ceratopeltis association

Samples from SCr-U are from two separate lithologies, each of which contains a distinct trilobite association. A thin (~0.5 cm) bioclastic rudstone (lithofacies as described in the section titled Bioclastic rudstone) contains abundant *Ceratopeltis* (Fig. 4b), with rare "*Peltabellia*," *Jeffersonia*, and *Licnocephala*. *Bolbocephalus* was not recovered in this association. The small slabs are of uniform lithology and thickness and likely represent a single bed.

#### **Bolbocephalus** association

A second association was recovered from 5–8 cm thick nodular lime mudstones in the SCr-U interval. Fossils are rare in this association and are limited to isolated large sclerites on upper bedding surfaces, mostly of *Bolbocephalus ellesmerensis* (Fig. 4*c*) with some *L. sanddoelaensis*. This is the only association from which *Bolbocephalus* was recovered.

The extent to which the associations reflect small-scale environmental and ecological heterogeneity versus taphonomic processes is unclear. The *Licnocephala* and *Ceratopeltis* associations have quite different sclerite size distributions, however, suggesting a role for taphonomic sorting. Quantitative data for shallow-water Lower Ordovician trilobite successions are few but were summarized by Westrop and Adrain (1998) and Adrain et al. (2000). The Baumann Fiord associations are typical of nearshore, bathyurid-dominated associations that occurred through much of the Ordovician in Laurentia. Such associations (Adrain et al. 2000, fig. 14) have a mean species diversity of 3.

# Age

Hitherto, the age of member B of the Baumann Fiord Formation had not been established on the basis of published information on the fossils, but available evidence and the closest comparisons of the trilobites indicate that it belongs to the Tulean Stage. Barnes et al. (1981, col. 27) indicated a conodont age for the middle part of the formation (presumably from the carbonates of member B) on central Ellesmere and northwestern Devon islands as Fauna D. The Nygaard Bay Formation, the direct equivalent of members B and C of the Baumann Fiord Formation, is also of Fauna D age (Peel and Smith 1988; Smith and Bjerreskov 1992) and was shown as upper Fauna D (i.e., corresponding to the *deltatus–costatus* Zone) by Smith and Bjerreskov (1992, col. 1).

The trilobite species of member B are all new and hence permit no direct correlations with other Laurentian units. Nevertheless, they agree with a Tulean assignment. Conventional bathyurids are not common in the western United States successions studied by Ross (1951) and Hintze (1953) until the Tulean, but at least one species does appear as an extremely rare faunal element in the Stairsian. Fortey and Peel (1990, p. 13) claimed that "both Peltabellia and Licnocephala are recorded from Utah and Nevada through a fairly short mid-Canadian interval, embracing trilobite Zones F and G ...." This is not accurate, as *Peltabellia* is not known from Zone F. The sole putative record of Licnocephala from Zone F is a single fragmentary cranidium assigned by Hintze (1953, pl. 8, fig. 7) to "Licnocephala? sp." We have made new collections from the horizon from which this specimen was collected and have recovered librigenae and a pygidium (to be described elsewhere). The species is very rare but does appear to be a bathyurid. In addition, Terrell (1973, pl. 2, fig. 8) illustrated a single, densely tuberculate cranidium from Stairsian strata in the northern House Range, Utah, that also seems to be a bathyurid. We have made extensive collections from the lower member of the Fillmore Formation, including at the section (A-A) from which this specimen was reported, but we have not encountered this taxon. Bathyurids therefore appear to be present but extremely rare in Stairsian strata. Licnocephala and Peltabellia both have Tulean type species and are, with the aforementioned exception, restricted to Tulean strata in the Fillmore and Garden City formations of Utah and Idaho.

A similar sharp faunal turnover has been documented by Boyce (1989) in platform rocks of the St. George Group in western Newfoundland, in which species of *Peltabellia*, *Bolbocephalus*, and *Jeffersonia* appear at the base of the Tulean Barbace Cove Member of the Boat Harbour Formation (though Stairsian and Tulean strata are separated by a hiatus). Bathyurids are not known from the underlying Stairsian strata in Newfoundland. "*Peltabellia*" baumannensis from member B has its closest comparison with "*Peltabellia*" knighti Boyce, 1989, from the Barbace Cove Member.

Material assigned by Fortey and Peel (1983) to *Ceratopeltis latilimbata* Poulsen, 1937, is from the basal beds of the

Amdrup Member of the Wandel Valley Formation in northeastern Greenland. The base of the Amdrup Member was depicted by Smith and Bjerreskov (1992, col. 4) as uppermost Tulean in age, although a fauna from 50 m above the base described by Fortey (1986) is clearly Blackhillsian, with species shared with the Catoche Formation of western Newfoundland. Lastly, *Bolbocephalus* and *Jeffersonia* are not known anywhere from occurrences older than Tulean. Hence, the balance of evidence favours a Tulean age for member B.

Species assigned to *Licnocephala* and *Peltabellia* by Fortey and Peel (1990) from the Poulsen Cliff Formation of Washington Land, which underlies the Nygaard Bay Formation and is a lateral equivalent to member A of the Baumann Fiord Formation, are of uncertain age. Fauna D encompasses both the Stairsian and Tulean stages. On the basis of the sharp change in the trilobite faunas at the base of the Tulean in both the western United States and Newfoundland, the part of the Poulsen Cliff Formation from which the Fortey and Peel collections were made (48 m below the top) is probably also Tulean. Given that extremely rare bathyurids are present in the Stairsian of the western United States, however, a Stairsian age cannot be ruled out.

## Systematic paleontology

Illustrated specimens are stored in the collections of the Department of Invertebrate Palaeontology, Royal Ontario Museum, Toronto, Ontario with specimen number prefix ROM.

FamilyBathyuridae Walcott, 1886GenusLicnocephala Ross, 1951

TYPE SPECIES: *Licnocephala bicornuta* Ross, 1951, from the Garden City Formation of Idaho, USA.

OTHER SPECIES: Licnocephala cavigladius Hintze, 1953; Licnocephala ovata Ross, 1953; Licnocephala sanddoelaensis n.sp.; Licnocephala sminue Fortey and Peel, 1990; Licnocephala n.sp. A, herein.

REMARKS: The monophyly of *Licnocephala* as presently conceived is dubious. Although the type species is poorly known, it resembles the other Utah and Idaho species, *L. cavigladius* Hintze, 1953, and *L. ovata* Ross, 1953, in its long and laterally bowed anterior sections of the facial suture. *Licnocephala sminue* Fortey and Peel, 1990, from North Greenland, and *L. sanddoelaensis* n.sp. from Ellesmere Island are most similar to each other, but their relationship to the western taxa is less clear. Specific comparisons are made in the species discussion later in the paper, but consideration of the phylogenetic status of the group must await modern revision of the Ross–Hintze species and cladistic analysis of the bathyurids as a whole.

Another species originally assigned to *Licnocephala* is *Licnocephala longa* Kobayashi, 1955, described on the basis of two incomplete pygidia from the McKay Group of British Columbia and illustrated with dorsal views of the uncoated specimens (Kobayashi 1955, pl. 6, fig. 16, pl. 8, fig. 13). Fortey and Peel (1990, p. 19) considered that the species

**Fig. 5.** (5.1–5.10, 512, 5.13, 5.15, 5.16) *Licnocephala sanddoelaensis* n.sp., all from locality SCr-L. (5.1, 5.4, 5.7) Cranidium, dorsal, right lateral, and anterior views, ROM 56811, ×3. (5.2) Cranidium, dorsal view, ROM 56812, ×2.5. (5.3, 5.5, 5.6, 5.8) Cranidium, holotype, dorsal, oblique, right lateral, and anterior views, ROM 56813, ×4. (5.9, 5.12) Cranidium, dorsal and right lateral views, ROM 56814, ×5. (5.10) Cranidium, dorsal view, ROM 56815, ×4. (5.13) Cranidium, ventral view, ROM 56816, ×3. (5.15) Three cranidia, dorsal view, ROM 56817 (top), 56818 (middle), 56819 (bottom), ×3. (5.16) Cranidium, dorsal view, ROM 56820, ×4. (5.11, 5.14, 5.17) *Licnocephala* n.sp. A, both from locality SCr-L. (5.11) Cranidium, dorsal view, ROM 56821, ×3. (5.14, 5.17) Cranidium, dorsal and left lateral views, ROM 56822, ×2.

"may be better referred to *Punka*." In addition, Kobayashi's specimens may not be conspecific with each other. The holotype (Kobayashi 1955, pl. 6, fig. 16) appears to show the pleural and interpleural furrows incised only adaxially, with a broad border as in *Licnocephala*. The other specimen, however (Kobayashi 1955, pl. 8, fig. 13), seems to show the interpleural furrows incised much more abaxially. Like several of Kobayashi's McKay Group taxa, it is so poorly described that it is uninterpretable and at present should be considered a nomen dubium.

*Licnocephala sanddoelaensis* n.sp. (Figs. 5*a*–5*j*, 5*l*, 5*m*, 5*o*, 5*p*, 6, 7)

DERIVATION OF NAME: For Sanddöla Creek, the type locality.

TYPE AND FIGURED SPECIMENS: Holotype ROM 56813 and paratypes ROM 56811, 56812, 56814–56820, and 56823–56839, all from the Baumann Fiord Formation, near Sanddöla Creek, Bache Peninsula, Ellesmere Island, Nunavut, Arctic Canada.

DIAGNOSIS: Glabella elongate, low, subcylindrical, slightly waisted opposite posterior edge of palpebral lobe, with dorsal sculpture of anastomosing fine lines; librigena with field, posterior border, lateral border, and dorsal surface of genal spine all merged into broad, convex, unsculptured smooth area, furrows completely effaced posteriorly; eye large and librigenal field narrow; librigenal lateral border impressed anteriorly; pygidium with sagittal length 52%–56% width, broad border occupying 31%–33% sagittal length and 28%–32% anterior width; axis narrow and tapering, with five rings.

DESCRIPTION: Cranidium broad and low, with limited dorsal convexity; width across  $\beta$  95% sagittal length; width across  $\beta$  79% width across  $\delta$ ; dorsal sculpture smooth on anterior border, frontal area and preglabellar field, interocular and posterior fixigena, and palpebral lobe; glabella with very fine anastomosing terrace lines set obliquely to sagittal axis (Fig. 6); anterior border long, slightly longer sagittally than exsagittally, and flat; anterior margin describing smooth anterior arc; anterior border furrow short (sagittally, exsagittally), of similar length along course, sharply incised, describing even anteriorly directed arc except for subtle posterior bow in sagittal region; anterior sections of facial sutures strongly anteriorly divergent in front of palpebral lobes, maximum point of divergence just behind anterior border furrow, converging forward across anterior border; glabella bullet-shaped, axial furrows long and generally subparallel to slightly anteriorly convergent; axial furrows bowed inwards slightly opposite rear half of palpebral lobe to create posterior waisting of glabella; axial furrow contacting preglabellar furrow at distinct break in course in some

specimens (Figs. 5a, 5b) and with more rounded and gradational contact in others (Figs. 5c, 5j); preglabellar furrow usually with median angularity so as to give glabella a slightly pointed front, but in some specimens (Fig. 50) describing a more or less smooth anterior arc; axial and preglabellar furrows of similar narrow incision and moderate depth; interocular fixigena broad, sloping gently from palpebral lobe toward axial furrow, with very weak dorsal inflation; faint eye ridge expressed dorsally, running from anterior edge of palpebral lobe slightly anteromedially to contact axial furrow behind junction with preglabellar furrow (best visible in Fig. 5b, left side, and Figs. 5i and 5o, right side, but when obscure probably due to poor preservation); palpebral lobe large and subsemicircular, not inclined from transverse plane, anterior edge set farther adaxially than posterior edge; L0 about double length of posterior border, of same length sagittally and exsagittally, posterior margin describing gentle posterior arc, lacking sculpture; S0 very short, firmly inscribed but much more faintly so than axial furrow, shallower medially in most specimens, with weak posterior curvature running subparallel to posterior margin of L0; posterior fixigena of narrow, triangular strip along posterior extension; posterior border short, slightly longer distally, lacking sculpture; posterior border furrow similar in depth to axial furrow, longer and slightly deeper distally; doublure not preserved.

Librigena known from only one specimen preserved with external surface exposed (Fig. 7p) and several with internal surface exposed; lateral margin describes even and gentle lateral arc, continued posteriorly along abaxial edge of genal spine; lateral margin of lateral border and genal spine sharp and blade-like, librigena somewhat flattened near edge; posterior border not distinct from field and posterior border furrow fully effaced; posterior margin running without angle or interruption into adaxial edge of genal spine; genal spine long, about as long as rest of librigena, excluding anterior doublural projection, dorsally inflated with broad, rounded, unsculptured surface, terminating in sharp point, ventral aspect with distinct ridge running back from posteromedian edge of doublure, ventral aspect flattened and forming shelf behind doublure; lateral border deep and incised anteriorly, but completely effaced from about opposite rear of visual surface; lateral border as defined anteriorly quite narrow and flat; eye large, but visual surface not preserved on any specimen; field narrow at midlength of eye, slightly wider than lateral border at same point; doublure broad and flat, with sculpture (poorly preserved but visible in Fig. 7r) of multiple raised lines running subparallel to lateral margin.

Rostral plate, hypostome, and thorax not discovered or identified.

Pygidium with length 52%–56% width; anterior margin nearly transversely straight, bowed slightly back distal to fulcrum in front of small articulating facet; posterior margin



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describing broad, even curve; axis narrow, axial furrows posteriorly convergent, effaced posteriorly in some specimens (Figs. 7a, 7g), meeting to fully circumscribe axis in others (Figs. 7c, 7i); axis terminated short of anterior edge of border, separated by small strip of exoskeleton; five axial rings present, but fourth and fifth very effaced in many specimens; ring furrows weakly expressed to effaced; very broad border strongly expressed behind posterior pleural band of first segment, slightly broader laterally than medially, with weak dorsal inflation, sloping toward margin, with faint trace of interpleural furrows, particularly of second segment, proximally but otherwise furrows completely effaced on border, border lacking dorsal sculpture; sagittal length of pygidium in front of border 67%-69% overall length; width of pygidium exclusive of border 68%-72% overall width; first pleural furrow well impressed, running just past interior edge of border; anterior and posterior pleural bands of similar length, those of first segment running with normal inflation to pygidial margin; pleural furrows of segments 2-4 expressed on region adaxial to border, that of segment five very weakly expressed; interpleural furrows very faintly expressed; behind first segment, pleural bands and furrows suppressed on border except as noted previously; doublure broad, slightly ventrally concave, lacking any raised line sculpture on this broad, concave part, terminated adaxially by robust raised rim with fine terrace line sculpture.

REMARKS: Poulsen (1937) erected Niobe brevicauda on the basis of two pygidia, the holotype fragmentary and preserved in dorsal view and a second complete but crushed and preserved in ventral view, from the Cape Weber Formation of East Greenland. The holotype has a broad border that bears a dorsal sculpture of strong, somewhat irregular, raised lines. Its proportions seem different from the second specimen, with length greater with respect to width. As the second specimen is preserved ventrally, whether or not they are conspecific is at present unknowable. Poulsen (1946, pl. 23, fig. 14) later assigned a third pygidium from the Cape Weber Formation, preserved in dorsal view, to the species. This specimen shows no sign of the strong raised line sculpture on the border present in the holotype. In proportions, it is a good match for Poulsen's (1937) ventrally preserved specimen. Together, these two specimens are comparable to pygidia of L. sanddoelaensis. They are not conspecific, however. The specimen illustrated in 1946 has a broader border, whereas the specimen illustrated ventrally in 1937 clearly lacks the raised adaxial rim on the doublure.

The type species of *Licnocephala*, *L. bicornuta* Ross, 1951, is inadequately known, as it is based on a single small cranidium lacking posterior fixigenae and one librigena, plus a pygidium (Ross 1951, pl. 30, fig. 25), which Ross tentatively assigned. *Licnocephala bicornuta* differs from all subsequently assigned species, including *L. sanddoelaensis*, in the possession of a relatively small glabella and very long preglabellar field with broad frontal areas. The librigena has a nearly flat field and firmly incised lateral and posterior border furrows. All other librigenae of assigned species have a moderately to strongly inflated field and border furrows that are very broad and shallow and posteriorly obscure.

Licnocephala ovata Ross, 1953, is based on two incom-

**Fig. 6.** *Licnocephala sanddoelaensis* n.sp. from locality SCr-L. (6.1) Detail of glabella of ROM 56811 (Fig. 5.1), dorsal view, to show fine terrace line sculpture,  $\times 7.5$ . (6.2) Detail of glabella of ROM 56815 (Fig. 5.10), dorsal view, to show fine terrace line sculpture,  $\times 10$ .



plete cranidia from the upper Tulean of the Garden City Formation (one illustrated in open nomenclature by Ross 1951, pl. 28, figs. 4, 5, 9). The holotype specimen is small and almost certainly juvenile. Cranidia typical of *L. sanddoelaensis* are four to six times larger. *Licnocephala ovata* differs from *L. sanddoelaensis* and all other assigned species in its highly inflated glabella, which is hump-shaped in lateral profile. It differs further from *L. sanddoelaensis* in its much more strongly anteriorly divergent anterior facial sutures.

Hintze (1953) described L. cavigladius on the basis of large specimens from his Section G, including cranidia, librigenae, a hypostome, and pygidia. Ross (1953) assigned material from the Garden City Formation to Hintze's species. This material, however, represents at least two separate species. Among Ross's tails are two (1953, pl. 64, figs 27, 29) that closely resemble Hintze's pygidia of L. cavigladius. Two others (Ross 1953, pl. 64, figs 25, 28) are obviously much more semicircular in outline, with length considerably greater with respect to width than pygidia of L. cavigladius. Ross did not mention these differences in his text. The shape difference is not ontogenetic, as Hintze's pygidia of L. cavigladius are larger than Ross's semicircular pygidia, whereas one of Ross's cavigladia-like pygidia (1953, pl. 64, fig. 29) is smaller than them. Further, the librigenae illustrated by Ross (1953, pl. 64, figs. 10, 24) appear to have shorter genal spines than Hintze's, although this could conceivably be ontogenetic, as they are considerably smaller. Given that at least two species are confused in Ross's material, it is difficult to know whether the immature specimens he figured (1953, pl. 64, figs. 5, 8, 14, 15, 18-20, 22, 23) in fact belong to L. cavigladius or not. Two of his figured heads (1953, pl. 64, figs. 4, 7) and the two tails mentioned earlier are very similar to and probably conspecific with Hintze's Utah type material.

Licnocephala sanddoelaensis in similar to L. cavigladius in the overall morphology of its librigena, with an elongate genal spine and generally inflated cheek, with the inflation carrying onto the dorsal aspect of the genal spine. The lateral border furrow is also impressed only anteriorly (Hintze 1953, pl. 10, fig. 5a) (Figs. 7p, 7q). Cranidia of L. cavigladius have much more divergent anterior facial sutures and an anterior border that is longer relative to its width. The interocular fixigena of L. cavigladius is very narrow, so the palpebral lobe nearly abuts the glabella. That of L. sanddoelaensis is much broader, and the palpebral lobe is relatively smaller. The species share similar glabellar shape and waisting, though the glabella of L. cavigladius is longer relative to its width. Pygidia of the species are quite different. In L. cavigladius the border occupies a much greater area, with the impressed pleural area restricted to a small space near the axis. The border is also set off from the impressed pleural region by a distinct furrow and sharp break in slope in L. sanddoelaensis, but is nearly gradational with the pleural region in L. cavigladius. Lastly, the pygidial doublure of L. cavigladius lacks the prominent raised ridge around its interior rim characteristic of L. sanddoelaensis.

The species most similar to L. sanddoelaensis is L. sminue Fortey and Peel, 1990, from the Poulsen Cliff Formation of Washington Land, western North Greenland. As the Poulsen Cliff Formation is a direct lateral equivalent of member A of the Baumann Fiord Formation, L. sminue is likely older than L. sanddoelaensis. The two species are closely similar in general cranidial dimensions, but L. sanddoelaensis typically has a longer, narrower, and more prominently waisted glabella, a slightly longer (sagittally) preglabellar field, a shorter (sagittally, exsagittally) anterior border that is set off from the preglabellar field by an incised border furrow rather than a break in slope, S0 that is posteriorly arcuate versus flexed anteriorly in its median part, less prominent eye ridges, broader interocular fixigenae, and much smaller palpebral lobes. Librigenae are not especially well known in external features for either species, but that of L. sanddoelaensis (Fig. 7p) seems to lack a depression separating the swelling of the field from that of the dorsal aspect of the genal spine which is seen in L. sminue (Fortey and Peel 1990, fig. 4G). The lateral border furrow is also shallower and more weakly expressed in L. sanddoelaensis, and the lateral margin is less flattened and blade-like. Pygidia of L. sanddoelaensis have the axis and pleural region occupying a relatively greater area, and the flattened border a relatively smaller area, than in L. sminue. The first segment in L. sminue is bowed posteriorly but is much more transverse in L. sanddoelaensis. The axis is slightly narrower in L. sanddoelaensis, and it terminates in front of the border, whereas in L. sminue the rear of the axis contacts and slightly overhangs the border.

*Licnocephala* n.sp. A (Figs. 5k, 5n, 5q)

FIGURED SPECIMENS: Figured specimens ROM 56821 and 56822, from the Baumann Fiord Formation, near Sanddöla Creek, Bache Peninsula, Ellesmere Island, Nunavut, Arctic Canada.

REMARKS: Two cranidia differ from all others in the possession of a much more parallel-sided glabella, which has only very subtle waisting. The axial furrows are slightly anteriorly convergent opposite the front of the palpebral lobes, whereas they are plainly anteriorly divergent in the same position in L. sanddoelaensis. The anterior border is shorter and has more inflation and dorsal convexity, lacking the completely flat upper surface of that of L. sanddoelaensis. Strikingly, the anterior sections of the facial suture are only weakly anteriorly divergent in front of the palpebral lobes and are nearly subparallel. In L. sanddoelaensis, the sutures are strongly anteriorly divergent in this area. Lastly, one specimen (Fig. 5k) shows a very short preglabellar field, with the anterior border furrow bowed back to nearly contact the preglabellar furrow. The other specimen is damaged in this area, but does not obviously show the same morphology. The differences between these specimens are not ontogenetic, as the specimen shown in Fig. 5k is well within the size range of recovered L. sanddoelaensis cranidia. It appears that the specimens represent a second, rare, species of Licnocephala. No librigenae or pygidia that could be associated with them were recovered.

Genus *Peltabellia* Whittington, 1953 [synonym: *Biolgina* Maksimova, 1955]

TYPE SPECIES: *Jeffersonia peltabella* Ross, 1951, from the Garden City Formation of Idaho, USA.

OTHER SPECIES: Bathyurus amplimarginatus Billings, 1859; Jeffersonia crassimarginata Cullison, 1944; Peltabellia knighti Boyce, 1989; Peltabellia? lata Zhou and Fortey, 1986; Bathyurellus permarginatus Cullison, 1944; Biolgina sibirica Maksimova, 1955; Peltabellia willistoni Lochman, 1966.

REMARKS: *Peltabellia* is a taxon of uncertain monophyly that includes mostly poorly known species. The best known taxa are *Peltabellia peltabella*, the type species; *Peltabellia elegans* Fortey and Peel, 1990 (by far the most comprehensively known); and *Biolgina sibirica* Maksimova, 1955, the type species of *Biolgina* Maksimova, 1955. These species are united by their large horizontal palpebral lobes, their relatively long and steeply declined preglabellar fields, their subcylindrical anterior borders, and their pygidia with four axial rings and a very broad flattened border. We agree with Zhou and Fortey (1986) that *Biolgina* is a synonym of *Peltabellia*. Other species that have been assigned to the genus, however, are either so poorly known as to be nearly uninterpretable or are not obviously related to this core group of three species.

Whittington (1953, p. 662) did not diagnose *Peltabellia* when he erected it, but indicated that it included *Jeffersonia peltabella* Ross, 1951 (the type species), *Jeffersonia missouriensis* Cullison, 1944, *Bathyurellus permarginatus* Cullison, 1944, and *Bathyurus amplimarginatus* Billings, 1859 (all of which had been considered closely related to *peltabella* by Ross 1951), along with two species figured in open nomenclature by Hintze (1953). The type species, *P. peltabella* (Ross 1951), is densely but finely tuberculate, with an elongate, parallel-sided glabella, considerable cranidial convexity, a long preglabellar field, a steeply declined ante-



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**Fig. 7.** *Licnocephala sanddoelaensis* n.sp. from locality SCr-L except where noted. (7.1) Pygidium, dorsal view, ROM 56823, ×2.5. (7.2) Pygidium, dorsal view, ROM 56824, ×2.5. (7.3, 7.4, 7.6) Pygidium, dorsal, right lateral, and posterior views, ROM 56825, ×5. (7.5, 7.9, 7.12) Pygidium, left lateral, dorsal, and posterior views, ROM 56826, ×4. (7.7) Pygidium, dorsal view, ROM 56827, ×3 (SCr-U). (7.8, 7.11) Pygidium, dorsal and right lateral views, ROM 56828, ×4. (7.10) Two pygidia, dorsal and ventral views, ROM 56829 (dorsal, left) and 56830 (ventral, right), ×2.5. (7.13, 7.14) Pygidium, dorsal and posterior views, ROM 56833, ×5 (SCr-U). (7.17) Right librigena, internal view, ROM 56835, ×4. (7.19) Left librigena, internal view, ROM 56836, ×5. (7.20) Three pygidia, internal views, ROM 56837 (left), 56838 (right top), 56839 (right bottom), ×3.

rior region of the cranidium, a very short genal spine, and a subsemicircular pygidium.

Neither the type nor the other species assigned by Whittington (1953) are adequately known. Cullison (1944, p. 71, pl. 34, figs. 10-16) described J. missouriensis on the basis of two illustrated cranidia, a pygidium, and a partial thoracopygidium. Ross (1951, p. 76) contested Cullison's association of sclerites, which were from two separate localities. Ross (1951, pl. 15, fig. 15) figured one of Cullison's paratypes (which Cullison himself had not illustrated), a pygidium from the same locality as the holotype cranidium. Though as noted by Ross this pygidium is clearly different from the isolated one from a different locality figured by Cullison (1944, pl. 34, figs. 14, 15), this does not, as Ross claimed, seem to settle the question of sclerite associations. This is because the paratype cranidium figured by Cullison (1944, pl. 34, fig. 13) was considered conspecific with the holotype by both Ross (1951) and Whittington (1953), yet it is from the same locality as Cullison's illustrated paratype pygidium. Hence, cranidia of P. missouriensis appear to occur at both localities in question, and there are two different types of pygidia with which they may be associated. Lochman (1966, p. 542) claimed that the pygidium illustrated by Cullison was conspecific with her new P. willistoni, a claim impossible to evaluate given the paucity and quality of the material (see later in the paper). The correct association may only be possible with new fieldwork.

*Bathyurellus permarginatus* Cullison, 1944 (pl. 34, figs. 23, 24), was based on two pygidia, but these are obviously not conspecific. The holotype (Cullison 1944, pl. 34, fig. 23) is narrower than the paratype, has a more posteriorly declined first segment, and has a much broader axis that occupies more of the pygidial area. This species is a nomen dubium and should be restricted to its holotype pending the discovery of additional material.

*Bathyurus amplimarginatus* Billings, 1859, from the Romaine Formation of the Mingan Islands, Quebec, is unrevised in the modern era. Billings's (1859, figs. 12*a*, 12*b*) syntypes are a pygidium and fragmentary cranidium illustrated with line drawings. Twenhofel (1938, p. 71, pl. 10, fig. 13) figured a small photograph of the pygidium in dorsal view. The specimen has a very broad border and well-incised axial and pleural furrows on the proximal area. It seems as similar to pygidia of, for example, *Licnocephala sminue* Fortey and Peel, 1990, as to those of any other species currently assigned to *Peltabellia*. Billings's drawing indicates an associated cranidium with a long, parallel-sided glabella but is otherwise uninterpretable. Pending modern revision based on additional material, this species, too, should be restricted to its syntypes and considered a nomen dubium.

Of the open nomenclature species from Utah, one of

Hintze's (1953, pl. 9, figs. 8, 11, 12) species is from the lower Tulean (Hintzeia celsaora Zone of Ross et al. 1997). We are in the process of collecting and revising the entire Ibexian interval in both southern Idaho (Ross 1951) and western Utah (Hintze 1953; see Adrain et al. 2001, 2003) and have collected abundant material of this species. It is quite similar to the type species; not apparent on Hintze's broken cranidium, it also has a fairly long and steeply declined preglabellar field and a cephalic sculpture of scattered, moderate-sized tubercles. The second species considered a probable *Peltabellia* by Whittington (Hintze 1953, pl. 10, figs. 7–10) is from the upper Tulean (Protopliomerella contracta Zone of Ross et al. 1997). It shows little in the way of potential synapomorphies with P. peltabella. Hintze's specimens are not well preserved, but they appear to have a smooth sculpture, the glabella is low, the cranidia are not obviously vaulted and the preglabellar field is not obviously declined, and the genal spine is long. More information is required to assess the relationships of this species.

Following Whittington (1953), the next species to be assigned were Peltabellia willistoni Lochman, 1966, and a species described in open nomenclature by Shaw (1966). Peltabellia willistoni is based on two incomplete pygidia and is a nomen dubium. Given that the specimens are from subsurface well cores, it is unlikely that topotypic material will ever be available, and the species should be restricted to its types. Lochman assigned some of Cullison's (1944) illustrated pygidia from Missouri to her species, but the material is not sufficient for comparison. Peltabellia willistoni appears to represent a species similar to the unnamed lower Tulean taxon of Hintze (1953, pl. 9, figs. 8, 11, 12). Shaw assigned a fragmentary pygidium from the Highgate Formation of Vermont to Peltabellia. It is an indeterminate bathyurid, but could well represent Acidiphorus Raymond, 1925.

*Peltabellia* was discussed in detail by Zhou and Fortey (1986), who questionably assigned a species from the upper Tremadoc of north China to the genus. *Peltabellia? lata* Zhou and Fortey does not seem likely to be congeneric with the core species group, as it lacks almost all of their potential synapomorphies. It appears to have an elongate and flattened anterior border and, in particular, a pygidium in which pleural bands and furrows behind the first segment are well expressed over most of the dorsal surface of the pygidium. It entirely lacks the broad flattened border typical of *Peltabellia* and related bathyurids and instead has a dorsal sculpture of anastomosing terrace lines over much of the pleural region.

Lastly, Boyce (1989) described *P. knighti* from the Barbace Cove Member of the Boat Harbour Formation of western Newfoundland. This species is the closest bathyurid among described taxa to the new species erected in the next section **Fig. 8.** *"Peltabellia" baumannensis* n.sp. from locality SCr-L except where noted. (8.1, 8.4, 8.8) Cranidium, dorsal, left lateral, and anterior views, ROM 56840, ×5. (8.2) Cranidium, dorsal view, ROM 56841, ×4. (8.3, 8.6, 8.7, 8.10) Cranidium, holotype, dorsal, left lateral, anterior, and oblique views, ROM 56842, ×5. (8.5, 8.9, 8.11, 8.12) Cranidium, right lateral, anterior, dorsal, and anteroventral view, ROM 56843, ×5. (8.13) Right librigena, external view, ROM 56844, ×5. (8.14) Left librigena, internal view, ROM 56845, ×3. (8.15) Right librigena, external view, ROM 56846, ×7.5. (8.16) Cranidium, ventral view, ROM 56847, ×7.5 (SCr-U). (8.17) Left librigena, external view, ROM 56848, ×5. (8.18–8.20) Pygidium, right lateral, posterior, and dorsal views, ROM 56849, ×7.5 (SCr-U). (8.21, 8.24, 8.25) Pygidium, left lateral, dorsal, and posterior views, ROM 56850, ×6 (SCr-U). (8.22) Pygidium, dorsal view, ROM 56851, ×6 (SCr-U). (8.23, 8.26, 8.27) Pygidium, posterior, left lateral, and dorsal views, ROM 56852, ×6 (SCr-U).

and is compared in detail in the species discussion. The relationship of this species pair to the core group of *Peltabellia* is unclear. They have much more convex and dorsally inflated pygidia, which lack the broad, flattened border typical of the core group and other bathyurids. Instead, the border region in both species is dorsally concave and bows upward to a raised rim (more prominent in "Peltabellia" baumannensis). Librigenae differ from the core group in their deep posterior and lateral border furrows that join posteriorly to isolate the field. Although information for "P." knighti is sparse, both it and "P." baumannensis have very tall, nearly wall-like anterior cranidial borders, matched by the anterior part of the librigenal lateral border, and coupled with concomitantly deep, trench-like border furrows, a morphology unknown in the core group. "Peltabellia" knighti and "P." baumannensis could plausibly be assigned to a new bathyurid genus. As noted by Fortey (1979) and Zhou and Fortey (1986), however, the state of knowledge of early Ibexian bathyurids is generally poor. We prefer not to name a new genus pending the field-based revision in progress of the Ross-Hintze faunas and cladistic analysis of the family. We refer both species to "Peltabellia", recognizing that they may ultimately be classified elsewhere.

"Peltabellia" baumannensis n.sp. (Fig. 8)

DERIVATION OF NAME: For the Baumann Fiord Formation.

TYPE AND FIGURED SPECIMENS: Holotype ROM 56842 and paratypes ROM 56840, 56841, and 56843–56852, all from the Baumann Fiord Formation, near Sanddöla Creek, Bache Peninsula, Ellesmere Island, Nunavut, Arctic Canada.

DIAGNOSIS: Cranidial anterior border very tall (sagittally, exsagittally), forming vertical "wall," posteromedian part of which bows backward to nearly contact front of glabella; anterior border furrow very deep and trench-like; tall border and deep furrow also reflected on anterior part of librigena; pygidium with dorsally concave border region and prominent dorsally raised rim around margin; flattened area with terrace lines developed around ventrolateral aspect of pygidium beneath rim.

DESCRIPTION: Cranidium with sagittal length 66% width across posterior fixigena; anterior border extremely dorsally convex, anteroposteriorly flattened to form vertical "wall," posterior edge steep and vertical, anterior face with some anterior and anterodorsal convexity; anterior margin with straight, transverse middle part separated from oblique-posterior-trending lateral parts by more or less sharp angle; connective suture in anterior view describes W shape (Fig. 8i); wall-like anterior aspect of anterior border with fine, subparallel raised line sculpture; dorsal margin of anterior border in anterior view more or less horizontally straight on lateral part, bowed up to form median promontory; anterior border furrow very short (sagittally, exsagittally) and extremely deep, forming V-shaped well, base of which can be seen protruding lower than connective sutures in anterior view; anterior border furrow simple and inscribed beside anterior facial suture, lengthened in front of corner of glabella, closed off dorsally in median part, as rear of anterior border protrudes posteriorly to nearly touch anteromedial point of glabella; preglabellar field hidden by posteriorly overhanging anterior border, extremely short or absent; frontal area small and triangular, lacking sculpture, steeply declined; anterior sections of facial sutures moderately anteriorly divergent in front of palpebral lobes, divergent for entire course, nearly straight; palpebral lobe very large, subcircular; palpebral furrow not impressed; interocular fixigena very narrow and lacking dorsal sculpture or inflation, palpebral lobe nearly abutting glabella; glabella barrel-shaped, with maximum width opposite anterior part of palpebral lobe 89% (86%–91%) sagittal length (excluding L0), strong dorsal convexity in sagittal profile, posterior part held in horizontal plane, anterior part steeply declined nearly into vertical plane; glabella with dorsal sculpture of small, subdued, but densely crowded granules (not well preserved on most specimens, but clearly visible in Fig. 8k; glabellar furrows weakly expressed dorsally as shallow furrows with short transverse course; axial furrows quite wide and shallow, bowed laterally around glabella; posterior of glabellar with sharp margin at anterior of S0, bowed slightly anteriorly at median point; S0 long, longest sagittally, with sharply defined anterior and posterior margins and nearly flat (sagittally, exsagittally profile) bottom; L0 of similar length sagittally and exsagittally, somewhat posteriorly bowed, with dorsal sculpture similar to that on rear of glabella; posterior fixigena reduced to narrow strip along anterior aspect of posterolateral projection; posterior border furrow with slightly sinuous transverse course, much deeper than axial furrow, shorter than S0; posterior border convex and enrolled, longer distally, lacking obvious dorsal sculpture but poorly preserved.

Rostral plate, hypostome, and thorax not discovered or identified.

Librigena with large eye (visual surface not preserved on any specimen) set off from field by furrow; field convex, more so anteriorly, narrow anteriorly, broader posteriorly, lacking apparent sculpture; lateral border furrow narrow and entrenched anteriorly, progressively wider and shallower posteriorly, meeting posterior border furrow above base of



genal spine; posterior border furrow with short course, generally shallow; lateral border narrow and wall-like anteriorly, much broader and less convex posteriorly, no sculpture apparent, though preservation of surface is poor; genal spine becomes relatively shorter during ontogeny, fairly short in large specimens, tapering rapidly to sharp point; doublure broad, folded anteriorly beneath trench-wall-like anterior part of lateral border and border furrow.

Pygidium with sagittal length 58%-59% maximum anterior width; axis with sagittal length 81%-84% that of pygidium and anterior width 36%-38% that of pygidium; axis with four well-expressed rings, fifth not differentiated, but terminal piece occupies considerable length behind fourth ring, suggested dorsally undifferentiated fifth may be present; ring furrows well impressed and quite long, faint preannulus present behind first ring; rings longer medially than dorsolaterally, but lengthened again distally near axial furrow, with sculpture of subdued, scattered tubercles on dorsal surface (generally poorly preserved, but best seen in Fig. 8aa); axial furrow merged in triangular depression at each junction with pleural furrows, resembling irregular flattened area rather than linear furrow; axis moderately inflated and strongly raised above pleurae, rear raised and fully defined, blunt and U-shaped; anterior and posterior pleural bands subequal in length, lacking obvious dorsal sculpture but may not be preserved; pleural furrows similar in depth to axial furrow, slightly shorter than ring furrows; four pleural furrows impressed, fourth weaker than others; interpleural furrows very faint, expressed as fine lineation that extends to border but is not obviously connected to axial furrow; posterior pleural band of first segment extends to margin; all posterior bands terminate at fairly narrow, dorsally concave, border; pygidial posterior margin evenly rounded, flat in posterior view; border with rim-like edge forming vertical wall around rear of pygidium, convex dorsally, but tall and wall-like posteriorly (e.g., Fig. 8y), with sculpture of fine raised lines subparallel with margin on posterior aspect; wall-like rim structure more weakly expressed anteriorly; doublure and ventral aspect of pygidium unknown.

REMARKS: As discussed earlier, "Peltabellia" baumannensis is most similar to "P." knighti Boyce, 1989. Boyce (1989, pl. 28, figs. 5, 6) illustrated two cranidia of "P." knighti in dorsal view only. The anterior border appears to be missing from one of the specimens, and on the other (Boyce 1989, pl. 28, fig. 5) is only complete on the left part of the specimen. It is hence impossible to tell whether the species had the unusual sagittal morphology of the border seen in "P." baumannensis. It is clear, though, that the border was exsagittally short, tall, and wall-like, and this is reflected also in the anterior part of the librigenal lateral border (Boyce 1989, pl. 28, figs. 7, 8) as in "P." baumannensis (Figs. 8m, 8q). Librigenae of the species are also similar in their deep expression of the lateral and posterior border furrows, which meet posteriorly to isolate the field. Pygidia are comparable in their strongly inflated axes and pleural bands, along with a border region that is dorsally concave as opposed to the nearly flat form typical of species of Peltabellia. The species differ in that the glabella of "P." baumannensis is more barrel-shaped with a distinct lateral expansion half way along its length, whereas that of "P." knighti is slightly longer and more parallel-sided. Palpebral lobes on specimens of "P." baumannensis are not well preserved, but the feature appears to be larger (Fig. 8b, right side) than that of "P." knighti. Genal spines of "P." baumannensis librigenae are smaller relative to the main body of the librigena and more slender and slightly shorter than those of "P." knighti. Pygidial differences are very obvious, in that the pleurae of specimens of "P." knighti have only the first two pleural furrows expressed (along with the anterior pleural band of the third segment), whereas those of "P." baumannensis have the first four pleural furrows expressed. The border region is broader in "P." knighti, though this feature may be accentuated by the fact that all of the Newfoundland specimens are internal molds. Lastly, the pygidial margin of specimens of "P." baumannensis is much more strongly dorsally raised into a prominent rim.

Genus *Bolbocephalus* Whitfield, 1890 [synonym: *Rananasus* Cullison, 1944]

TYPE SPECIES: *Bathyurus? seelyi* Whitfield, 1886, from the Fort Cassin Formation of Vermont, USA (see Whittington 1953).

oTHER SPECIES: Bolbocephalus angustisulcatus Poulsen, 1927; ?Rananasus brevicephalus Cullison, 1944; Rananasus conicus Cullison, 1944; Dolichometopus? convexus Billings, 1865 (see Fortey 1979); Bolbocephalus ellesmerensis n.sp.; Bolbocephalus glaber Poulsen, 1927; Bolbocephalus groenlandicus Poulsen, 1937; Bolbocephalus jeffersonensis Cullison, 1944; Bolbocephalus kindlei Boyce, 1989; Bolbocephalus saintclairi Cullison, 1944; Bolbocephalus stevensi Boyce, 1989; Bathyurus? truncatus Whitfield, 1890.

REMARKS: Opinion has varied on the status of Gignopeltis Raymond, 1924, which is known from a unique holotype pygidium of the type species, Dolichometopus? rarus Billings, 1865, from the Oxford Formation of southern Ontario (see Ludvigsen, 1979). Ludvigsen (1979) and Fortey (1979) considered Gignopeltis a probable junior synonym of Bolbocephalus, based on similarity with the pygidium of Bolbocephalus convexus (Billings 1865). Boyce (1989) argued that it may instead be a synonym of Benthamaspis Poulsen, 1946. There are problems with both suggestions. Bolbocephalus convexus has an effaced pygidium, but all assigned specimens clearly show the general genus condition of interpleural furrows that are much deeper distally than proximally (see later in the paper). The unique holotype of Gignopeltis rara shows no trace of this feature. Pygidia of species of Benthamaspis usually have the first segment expressed on the pleural region and all posterior ones completely effaced. Gignopeltis rara lacks this condition, instead showing distinct second and third pleural furrows. Many species of *Benthamaspis* have a pygidial postaxial ridge that is connected to the rear of the axis (the species upon which Boyce based his argument, his new Benthamaspis hintzei, has a weak ridge; Boyce 1989, pl. 32, figs. 6, 7), but this feature is obviously lacking in G. rara, in which the axial furrows remain deep posteriorly and meet medially to circumscribe the axis. An alternative comparison of Gignopeltis is with Strigigenalis cassinensis Whittington, 1953, the type species of Strigigenalis Whittington and Ross in Whittington,

1953. Whittington (1953, pl. 69, figs. 23-25) misassigned pygidia of an effaced species of Bolbocephalus (B. truncatus (Whitfield 1890)) to this species but figured the correct pygidium in open nomenclature (Whittington 1953, pl. 68, figs. 30, 32). Fortey (1979) recognized that Whittington had incorrectly identified the pygidium of Strigigenalis, but listed (Fortey 1979, p. 88) the correct pygidium as a synonym of Strigigenalis caudata (Billings 1865). Brett and Westrop (1996, figs. 17.1, 17.2, 17.7-17.9) corrected the association and illustrated additional pygidia. The pygidium of G. rara (see Ludvigsen 1979, pl. 1, fig. 4) has a margin that flattens posteriorly and comes to a spatulate point (albeit a subtle one) posteromedially. This is the same morphology that is much more strongly developed in S. cassinensis, and it seems possible that the taxa are related. Gignopeltis has priority over *Strigigenalis*, but in the present state of knowledge we agree with previous authors that Gignopeltis is best restricted to its unique holotype.

Cullison (1944) erected Rananasus for two species from the Rich Fountain Formation of Missouri. His diagnosis begins "Cephalon consists of a large cranidium and two very small free cheeks." Librigenae, however, are unknown for either of the species Cullison assigned. The type species, Rananasus conicus Cullison, 1944 (pl. 34, figs. 36-40), is a convex, effaced taxon closely comparable to B. convexus. The glabella is inflated, waisted posteriorly, expands forward, and overhangs the anterior border only slightly more than in B. convexus (cf. Cullison 1944, pl. 34, fig. 37, with Fortey 1979, pl. 26, figs. 3, 4). The pygidium of R. conicus appears to have somewhat narrower pleural regions than that of B. convexus, but it is otherwise very similar. The species seem certain to be closely related, and hence we consider Rananasus a junior subjective synonym of Bolbocephalus. The second species assigned to *Rananasus* by Cullison, R. brevicephalus, is represented by small cranidia that are difficult to interpret based on Cullison's photographs. The pygidium (Cullison 1944, pl. 34, fig. 44) appears similar to that of B. conicus. The affinities of brevicephalus are uncertain pending revision of the types and discovery of new material.

There has been little discussion of the possible relationships of Bolbocephalus. Whittington (1953, p. 657) noted similarity in the cephala of Bolbocephalus and Petigurus Raymond, 1913. This is accurate; although the glabellae of species of Petigurus are certainly more parallel-sided than those of species of Bolbocephalus, the axial furrows in Petigurus are posteriorly bowed inward and diverge anteriorly around an inflated, anteriorly protruding frontal part of the glabella. The description here of a well-preserved librigena (Fig. 9j) of a less effaced species of Bolbocephalus furthers the comparison, as it is nearly identical in proportions to the librigena of Petigurus nero (Billings 1865; see Fortey 1979, pl. 29, fig. 1), differing mainly in the presence of a finely granulate versus coarsely tuberculate sculpture. Chatterton (1994, p. 541) considered that Petigurus was comparable to the dimeropygid Ischyrotoma Raymond, 1925, and particularly Ischyrotoma twenhofeli Raymond, 1925, from the Shallow Bay Formation of Newfoundland. Chatterton suggested that Petigurus "should be considered when examining the relationship between these families [i.e., Bathyuridae and Dimeropygidae]." Similarities between Petigurus and Ischyro*toma* are almost certainly superficial, consisting mainly of coarsely tuberculate sculpture on a vaulted exoskeleton. Pygidia of *Petigurus* are not at all comparable to those of *Ischyrotoma* (see the examples in Adrain et al. 2001), which are small, subtriangular, and medially bowed in posterior view and have simple and complete pleural and interpleural furrows.

Not mentioned previously is that some pygidial features of Petigurus are apparently uniquely shared with Bolbocephalus. In particular, the pleural furrows of Petigurus nero are deep and extend distally across the fulcrum to nearly contact the border. The interpleural furrows, however, are deep only distally and are shallowed to at most a faint lineation or else are completely obsolete proximally (e.g., Fortey 1979, pl. 29, figs. 8–10). Exactly the same morphology is seen in the pygidium of B. ellesmerensis n.sp. (Fig. 9i). In addition, the pygidium of *B. ellesmerensis* has a very similar axis, with four transverse, well-defined axial rings and a fifth poorly differentiated from a broad terminal piece (cf. Fig. 9i with Fortey 1979, pl. 29, fig. 8). Pygidia of Petigurus groenlandicus have more complete interpleural furrows (Poulsen 1937, pl. 6, figs. 11-13), although they are still clearly more deeply impressed distally. The pygidium of the youngest species, Petigurus inexpectatus Fortey and Droser, 1996, has the pleural regions greatly reduced in size relative to the axis. Nevertheless, the first interpleural furrow shows the distally deepened condition (Fortey and Droser 1996, figs. 7.4, 7.6, 7.7), as it is represented by an impressed slot set distal to the fulcrum but is completely effaced proximally. The condition can be observed in all species of *Bolbocephalus*, though it is generally less pronounced than in B. ellesmerensis. Even in convex and effaced species such as B. stevensi Boyce, 1989, and B. convexus (Billings 1865), the laterally impressed condition of the interpleural furrows can be made out (Boyce 1989, pl. 24, fig. 1; Fortey 1979, pl. 26, fig. 8, right-hand side). It seems likely that this condition, along with the cephalic similarities, is synapomorphic, and that Bolbocephalus and Petigurus together form a clade.

It is less clear whether the genera are monophyletic sister taxa or whether the generally younger Petigurus shares ancestry with one or more species currently assigned to Bolbocephalus (i.e., that Bolbocephalus is paraphyletic). This is difficult to evaluate in the current state of knowledge. The type species, B. seelyi, however, shares with B. convexus, B. groenlandicus, and B. truncatus (assuming Bolbocephalus? sp. indet. of Whittington (1953, pl. 66, figs. 11, 15, 16) is the cranidium of B. truncatus) a dorsal cephalic sculpture of fine anastomosing lines (not well expressed in Whittington's photographs of the poorly preserved large specimens of B. seelvi, but documented in his written description) and librigenae with reduced or absent genal spines (not known for B. groenlandicus or B. truncatus). Bolbocephalus convexus, B. truncatus, and B. groenlandicus share a vaulted, more or less effaced pygidium. That of B. seelyi is less vaulted and has wellimpressed furrows. It is possible that B. seelyi is a basal member of a clade that developed the anastomosing sculpture and ultimately the lost genal spine and vaulted morphology of B. convexus. The morphology of B. ellesmerensis n.sp. is in many ways more similar to that of species of Petigurus, all of which are younger. It has a long genal spine similar in size to that of *P. nero*, and its pygidium is broad like those of Petigurus (though caution is necessary in com-



**Fig. 9.** *Bolbocephalus ellesmerensis* n.sp., all from locality SCr-U. (9.1, 9.3, 9.4, 9.7) Cranidium, dorsal, anterior, left lateral, and oblique views, ROM 56853, ×4. (9.2) Cranidium, dorsal view, ROM 56854, ×2. (9.5) Cranidium with librigena (see Fig. 9.10), dorsal view, ROM 56855 (librigena ROM 56856), ×1.5. (9.6, 9.8) Cranidium, dorsal and right lateral views, ROM 56857, ×3. (9.9, 9.11) Pygidium, holotype, dorsal and posterior views, ROM 56858, ×2. (9.10) Left librigena (see Fig. 9.5), external view, ROM 56856, ×5.

parison, as the only known pygidium of *B. ellesmerensis* has been somewhat flattened). Strikingly, it also has a finely tuberculate cephalic sculpture, with no sign of the fine raised lines present in species close to the type. It is conceivable that *B. ellesmerensis* is actually an early member of the *Petigurus* clade, but pending further discoveries it is assigned to *Bolbocephalus*.

# **Bolbocephalus ellesmerensis** n.sp. (Fig. 9)

DERIVATION OF NAME: For Ellesmere Island.

TYPE AND FIGURED SPECIMENS: Holotype ROM 56858 and paratypes ROM 56853–56857, all from the Baumann Fiord Formation, near Sanddöla Creek, Bache Peninsula, Ellesmere Island, Nunavut, Arctic Canada.

DIAGNOSIS: Cephalic sculpture of densely spaced but very fine tubercles and granules; librigenal lateral border furrow well impressed; genal spine long (for genus) and tapering; pygidium broad and relatively flat, with very deep pleural furrows and interpleural furrows which are deep distally but reduced to a fine lineation proximally.

DESCRIPTION: Cranidium with sagittal length 58% maximum width across posterior fixgenae; glabella, L0, and posterior border with sculpture of dense but very fine and subdued tubercles and granules (possibly present on other dorsal surfaces but obscured by preservation); glabella with sagittal length (excluding L0) 117% maximum width opposite front of palpebral lobe; glabella inflated, posterior part gently dorsally arcuate in sagittal profile, anterior part strongly curved and protruding forward and downward; axial furrows deep, continuous opposite L0, slightly anterior convergent in front of L0, strongly anteriorly divergent opposite rear third of palpebral lobe, bowing strongly laterally then converging anteriorly to run without interruption or break in course into preglabellar furrow of same depth; anterior border area not well preserved on any specimen, but no distinction is apparent between border and preglabellar field; front area a narrow strip of exoskeleton, wider abaxially and curving around glabellar to run into interocular fixigena; palpebral lobe large, with midlength about half way along glabella; palpebral furrow shallow, effaced posteriorly; interocular fixigena wider posteriorly, running into broad area of posterior fixigenae opposite basally constricted glabella; very faint ovate dorsal swelling on posterior fixigenae adjacent to axial furrow opposite base of glabella; S0 more incised than axial furrow (except specimen in Fig. 9b which is flattened), with steeper anterior slope defining rear of glabellar than posterior slope defining front of L0, course nearly exactly transverse; L0 trapezoidal in plan view, widening posteriorly, very slightly longer sagittally than exsagittally, median node not evident; posterior border furrow deep, initially transverse but deflected posteriorly at adaxially set fulcrum; very short and distally shortening strip of posterior fixigena in front of posterior border furrow; posterior border inflated, longer distally than proximally.

Librigena with field moderately inflated, sculpture of densely scattered, very fine tubercles; field narrowest opposite about one third length of eve (from front); eve socle of single prominent band, of similar length along course, set off from field by broad furrow and from visual surface by narrow, incised furrow; eye long and low; lateral border furrow narrow and incised anteriorly, broader and much shallower posteriorly, intersecting posterior border furrow in broad and long triangular depression well in front of genal spine base; posterior border furrow developed only distally on librigena, cut by facial suture near adaxial edge of field; lateral border narrow and cylindrical anteriorly, steadily broadening posteriorly, very broad and apparently somewhat flattened posteriorly, with prominent sculpture of dense tubercles slightly finer than those on field; posterior margin describes even and shallow lateral arc with no change in slope at genal spine; posterior section of facial suture very long; genal spine just over half exsagittal length of field, tapering rapidly to a point and lacking preserved sculpture on single available specimen.

Rostral plate, hypostome, and thorax not discovered or identified.

Pygidium known from single large but crushed specimen (Figs. 9i, 9k); sagittal length about 60% maximum width; dorsal surface with smooth sculpture everywhere; axis with four clearly defined rings; fifth ring probably present in front of broad terminal piece but obscured by poor preservation in only available specimen; axial furrows posteriorly convergent, bowed around each axial ring, bowed posteriorly around expanded fifth ring and terminal piece, shallowed behind axis, axis differentiated posteriorly mainly by break in slope; axial rings of similar length medially and laterally; ring furrows shallow, first and second slightly deeper adaxially; first four pleural furrows deeply impressed; interpleural furrows represented by shallow lineation proximally, deep and incised distally, four expressed though fourth faint; border present as narrow rim at which furrows terminate if not effaced adaxially; posteromedian area broad and smooth in front of border and behind axis; pygidial margin describing nearly even arc.

REMARKS: The possibility of a relationship between *B. ellesmerensis* n.sp. and species assigned to *Petigurus* was discussed earlier. It is not particularly similar in detail to any of the named species of *Bolbocephalus* but is perhaps closest to *B. stevensi* Boyce, 1989, from the Barbace Cove Member of the Boat Harbour Formation, western Newfoundland. The species share a relatively flat pygidium with well-incised furrows, in contrast with the more vaulted and variably effaced form with reduced pleural area typical of many other species.

Genus Ceratopeltis Poulsen, 1937

OTHER SPECIES: Ceratopeltis bachensis n.sp.; Ceratopeltis forteyi n.sp.

REMARKS: Ceratopeltis latilimbata was named by Poulsen (1937, p. 57, pl. 7, fig. 14) on the basis of a single poorly preserved pygidium from the Cape Weber Formation, Kap Weber, Andrée Land, East Greenland. Fortey and Peel (1983) illustrated material from the Amdrup Member of the Wandel Valley Formation, collected at Kap Holbæk, Danmark Fjord, eastern North Greenland (approximately 800 km distant from Poulsen's type locality), and assigned it to C. latilimbata. A species of Ceratopeltis from the Baumann Fiord Formation is clearly distinct from the Kap Holbæk species. Poulsen's unique holotype of C. latilimbata is so poorly preserved, however, that it is impossible to know whether it is conspecific with either the North Greenland or Ellesmere Island species. The most obvious distinction between the latter is in the size, shape, and spacing of the median pair of pygidial border spines. These are not distinct on Poulsen's poorly preserved holotype of C. latilimbata, but if Fortey and Peel's (1983, pl. 6, fig. 2) indication of their original shape is accurate, C. latilimbata is distinguished from the other species in its much broader median spines. In any case, a claim of species identity based on negative evidence (poor preservation and small sample size) should likely be avoided, as it has significant biostratigraphic and biogeographic implications that may not be supported. That the three occurrences together constitute a highly distinctive clade of bathyurids is not at issue, and there is no reason to abandon Ceratopeltis. The best course of action is to restrict Poulsen's type species to its poorly preserved unique holotype pending the recovery of new material from the Cape Weber Formation and to regard the North Greenland and Ellesmere taxa as reasonably well known distinct species. Hence, we propose the new name Ceratopeltis forteyi for the taxon from the Amdrup Member treated by Fortey and Peel (1983) and describe the Baumann Fiord Formation species as Ceratopeltis bachensis n.sp.

## Ceratopeltis forteyi n.sp.

1983 *Ceratopeltis latilimbata* Poulsen (partim); Fortey and Peel, p. 52, text fig. 2, pl. 6, figs. 3-10, 11? (only; pl. 6, figs. 1, 2 = C. *latilimbata* Poulsen).

DERIVATION OF NAME: For Richard A. Fortey.

TYPE SPECIMEN: Holotype MGUH 16.049 (MGUH, Geological Museum in Copenhagen, Copenhagen, Denmark; Fortey and Peel 1983, pl. 6, fig. 5), from the Amdrup Member, Wandel Valley Formation, Kap Holbæk, Danmark Fjord, eastern North Greenland.

DIAGNOSIS: Median pygidial spine pair closely spaced, with long axes slightly posteriorly convergent, and extending posteriorly past tips of lateral spine pair; librigenal field broad; eye relatively small.

REMARKS: *Ceratopeltis forteyi* was described in detail (as *C. latilimbata*) by Fortey and Peel (1983, p. 53). It is compared with *C. bachensis* n.sp. in the following Remarks section.

*Ceratopeltis bachensis* n.sp. (Fig. 10*a*-10*m*, 10*q*)

DERIVATION OF NAME: For the Bache Peninsula.

TYPE AND FIGURED SPECIMENS: Holotype ROM 56864 and paratypes ROM 56859–56863, and 56865–56875, all from the Baumann Fiord Formation, near Sanddöla Creek, Bache Peninsula, Ellesmere Island, Nunavut, Arctic Canada.

DIAGNOSIS: Inner pair of pygidial spines broad and widely divergent with tips well separated; genal spine long; librigenal field narrow; eye large.

REMARKS: Ceratopeltis bachensis is similar to C. forteyi, and both species are fairly coarsely preserved. Extended written description is considered unnecessary, with all contrasts between the species noted in the following discussion. Ceratopeltis bachensis differs from C. forteyi (see Fortey and Peel 1983, pl. 6) most obviously in the shape and disposition of its medial pygidial spine pair. In C. forteyi, the spines are close together, such that an exsagittal line bisecting one of the spines would be approximately aligned with, or only a little exsagittal of, the axial furrow. The spine tips are close together, and the space between them is a sharply notched inverted V. The long axes of the spines are slightly posteriorly convergent. In C. bachensis, an exsagittal line bisecting one of the medial spines runs up the pleura, well abaxial of the axial furrows. The medial spines are markedly posteriorly divergent and are separated by a much broader space, describing a shallower inverted V than in C. forteyi. Fortey and Peel (1983, pl. 6, fig. 11) illustrated one pygidium in ventral view that is more like C. bachensis, though apparently with shorter and blunter interior spines, and a second (1983, pl. 6, fig. 6) that could possibly be similar but is impossible to interpret due to poor preservation. The other four pygidia they illustrated (1983, pl. 6, figs. 3, 5, 7, 8) clearly show the elongate, crowded interior spines. Every single example recovered from the Baumann Fiord Formation at Sanddöla Creek has the same widely spaced morphology, and it seems certain that different taxa are represented. It is possible that Fortey and Peel's single specimen with more widely spaced spines represents C. bachensis, i.e., that two species of Ceratopeltis occur in the Wandel Valley Formation. Alternatively, it could represent intraspecific variation, but it is odd that no similar variation can be observed in the large sample from Sanddöla Creek, nor is such a level of variation seen in other well-constrained bathyurid samples. Ceratopeltis bachensis further differs from C. forteyi in librigenal morphology. The genal spine is relatively longer, with a more robust base, and in particular the librigenal field is considerably narrower (cf. Figs. 10c, 10g, and 10h, with Fortey and Peel 1983, pl. 6, fig. 4). The available cranidia from the Baumann Fiord are very poorly preserved. Nevertheless, one retains what appears to be a complete palpebral lobe (Fig. 10b, right-hand specimen). This is much larger than that of C. forteyi (Fortey and Peel 1983, pl. 6, fig. 9, both sides, fig. 10, lefthand side). This matches the presumptive size of the eye. The visual surface is not preserved in any of the Baumann Fiord librigenae, but the broken space where it is absent is larger than the area with the visual surface preserved in C. forteyi (Fortey and Peel 1983, pl. 6, fig. 4).

Fig. 10. (10.1–10.13, 10.17) Ceratopeltis bachensis n.sp., all from locality SCr-U. (10.1) Cranidium, dorsal view, ROM 56859, ×7.5. (10.2) Two cranidia, dorsal views, ROM 56860 (left) and 56861 (right), ×7.5. (10.3) Right librigena, external view, ROM 56862, ×10. (10.4) Pygidium, dorsal view, ROM 56863, ×10. (10.5) Pygidium, holotype, dorsal view, ROM 56864, ×7.5. (10.6) Pygidium, dorsal view, ROM 56865, ×7.5. (10.7) Left librigena, external view, ROM 56866, ×7.5. (10.8) Right librigena, external view, ROM 56867, ×10. (10.9) Pygidium, dorsal view, ROM 56868, ×10. (10.10) Pygidium, dorsal view, ROM 56869, ×10. (10.11) Pygidium, dorsal view, ROM 56870, ×10. (10.12) Pygidium, dorsal view, ROM 56871, ×10. (10.13) Pygidium, dorsal view, ROM 56872, ×7.5. (10.17) Three pygidia, dorsal views, ROM 56876, ×5. (10.15, 10.16) Pygidium, dorsal and right lateral views, ROM 56877, ×5.



Genus *Jeffersonia* Poulsen, 1927 [probable synonym: *Bathyurina* Poulsen, 1937]

TYPE SPECIES: *Jeffersonia exterminata* Poulsen, 1927, from the Nunatami Formation of Greenland.

*Jeffersonia* sp. (Figs. 10*n*-10*p*)

MATERIAL: Figured specimens ROM 56876 and 56877, from

the Baumann Fiord Formation, near Sanddöla Creek, Bache Peninsula, Ellesmere Island, Nunavut, Arctic Canada.

REMARKS: Fortey (1986, p. 18) discussed the probable synonymy of *Jeffersonia* and *Bathyurina*, which is complicated by the fact that the pygidium of the type species of *Bathyurina* (*Bathyurina megalops* Poulsen, 1937, from the Cape Weber Formation, East Greenland) and the cranidium of the type species of *Jeffersonia* are unknown. In addition to those species, *Jeffersonia* includes *Bathyurus timon* Billings, 1865

(see Fortey 1979, 1986, 1992) and several poorly known species from Missouri described by Cullison (1944). A poorly preserved cranidium (Fig. 10n) and a better preserved pygidium (Fig. 100), both from the Ceratopeltis association, are apparently conspecific and probably referable to Jeffersonia. The cranidium resembles species of *Jeffersonia* in its very elongate, parallel-sided glabella, but differs from Jeffersonia timon, for example, in having the anterior border region relatively flat rather than steeply downsloping. The pygidium shows the well-impressed furrows typical of Jeffersonia and is probably most closely comparable with the unique holotype of Jeffersonia exterminata (Poulsen 1927, pl. 20, fig. 28), which it resembles in the possession of a relatively broad border. The pygidial axis, however, is shorter and less posteriorly tapering than that in J. exterminata. The pygidium is broader relative to its sagittal length than that of J. timon and has a broader border.

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