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A new lower Cambrian eodiscoid trilobite fauna from Swedish Lapland and its implications for intercontinental correlation

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Abstract – A lower Cambrian eodiscoid trilobite fauna and an associated holmiid trilobite, *Holmia* sp., are described from a bioclastic limestone at the top of the Torneträsk Formation in the Luobákti section, south of Lake Torneträsk, northern Sweden. Other associated polymerid trilobites include *Orodes*? *lapponica* and *Strenuaeva inflata*. The precise age of the trilobite fauna cannot be determined, but its generic composition and stratigraphical position at the top of the lower Cambrian suggest that it was recovered from the *Ornamentaspis*? *linnarssoni* Assemblage Zone. Two species of eodiscoids are present: *Neocobboldia* aff. *dentata* and *Chelediscus acifer*. The latter species is known previously from England and southeastern Newfoundland, and provides a novel link between upper lower Cambrian successions in Baltica and Avalonia.

Keywords: eodiscoids, trilobites, correlation, biostratigraphy, lower Cambrian, Sweden.

1. Introduction

The Eodiscina comprise small, isopygous trilobites possessing only two or three thoracic segments and a generally fully segmented pygidial axis. Eyes and proparian facial sutures may be present. Eodiscoids are characteristic elements of many Cambrian faunas, with several geographically widespread genera and species that provide a basis for long-distance correlations of upper lower Cambrian and lower middle Cambrian strata (e.g. Robison *et al*. 1977; Ahlberg & Bergström, 1993; Geyer & Shergold, 2000; Geyer, 2005). In the lower Cambrian of Scandinavia they are generally rare, and hitherto only two species have been described: *Calodiscus lobatus* (Hall, 1847) and *Runcinodiscus* cf. *index* Rushton *in* Bassett, Owens & Rushton, 1976 (e.g. Ahlberg, 1983, 1984). The former species is common in the *Holmia kjerulfi* Assemblage Zone and has been recorded from the Gärdsjön Formation of Jämtland, central Sweden, and from the Gislöv Formation of Scania, southern Sweden (Ahlberg, 1984; Ahlberg & Bergström, 1993; Cederström, Ahlberg & Clarkson, 2005). Recently, it was also recorded from the Evjevik Limestone (*Ornamentaspis*? *linnarssoni* Assemblage Zone) at Skyberg in the Mjøsa district, southeastern Norway (J. Ahlgren, Mariestad, pers. comm. 2006). The presence of *R*. cf. *index* (*Weymouthia nobilis* Ford of Kiær, 1917) in the lower Cambrian of Scandinavia is based on a single pygidium from the Holmia Shale (*H. kjerulfi* Assemblage Zone) at Tømten in the Mjøsa district (Ahlberg, 1984). Furthermore, a yet unpublished find of *Luvsanodiscus* cf. *gammatus* Korobov, 1980, from the Gärdsjön Formation of Jämtland has been noted by one of the authors (PC).

This paper reports the first occurrence in Baltica of two additional eodiscoids, *Chelediscus acifer* Rushton, 1966, and *Neocobboldia* aff. *dentata* (Lermontova, 1940), recovered from the upper lower Cambrian in the Torneträsk area of northern Swedish Lapland. Their potential for long-distance correlations is discussed herein.

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2. Geological setting

In Scandinavia, lower Cambrian deposits crop out in a narrow sinuous belt along the eastern front of the Caledonides (Fig. 1). West and northwest of the Caledonian Front, the autochthonous sedimentary rocks are generally superimposed by allochthonous units, thrusted onto the Baltoscandian Platform during the Caledonian Orogeny (Roberts & Gee, 1985). The autochthonous sedimentary succession along the Caledonian Front of northern Scandinavia consists predominantly of siliciclastic rocks and is referred to as the Dividalen Group. It has a thickness of 100–200 m and rests with a profound unconformity on a Proterozoic or Archaean crystalline basement. The general succession has been worked out mainly by Moberg (1908), Vogt (1918, 1967), Kulling (1964) and Føyn (1967). The lithostratigraphy was subsequently revised by Thelander (1982), who distinguished two major units within the Dividalen Group: the Torneträsk Formation and the overlying Alum Shale Formation. He further subdivided the Torneträsk Formation into five members, in descending order: the Upper siltstone,

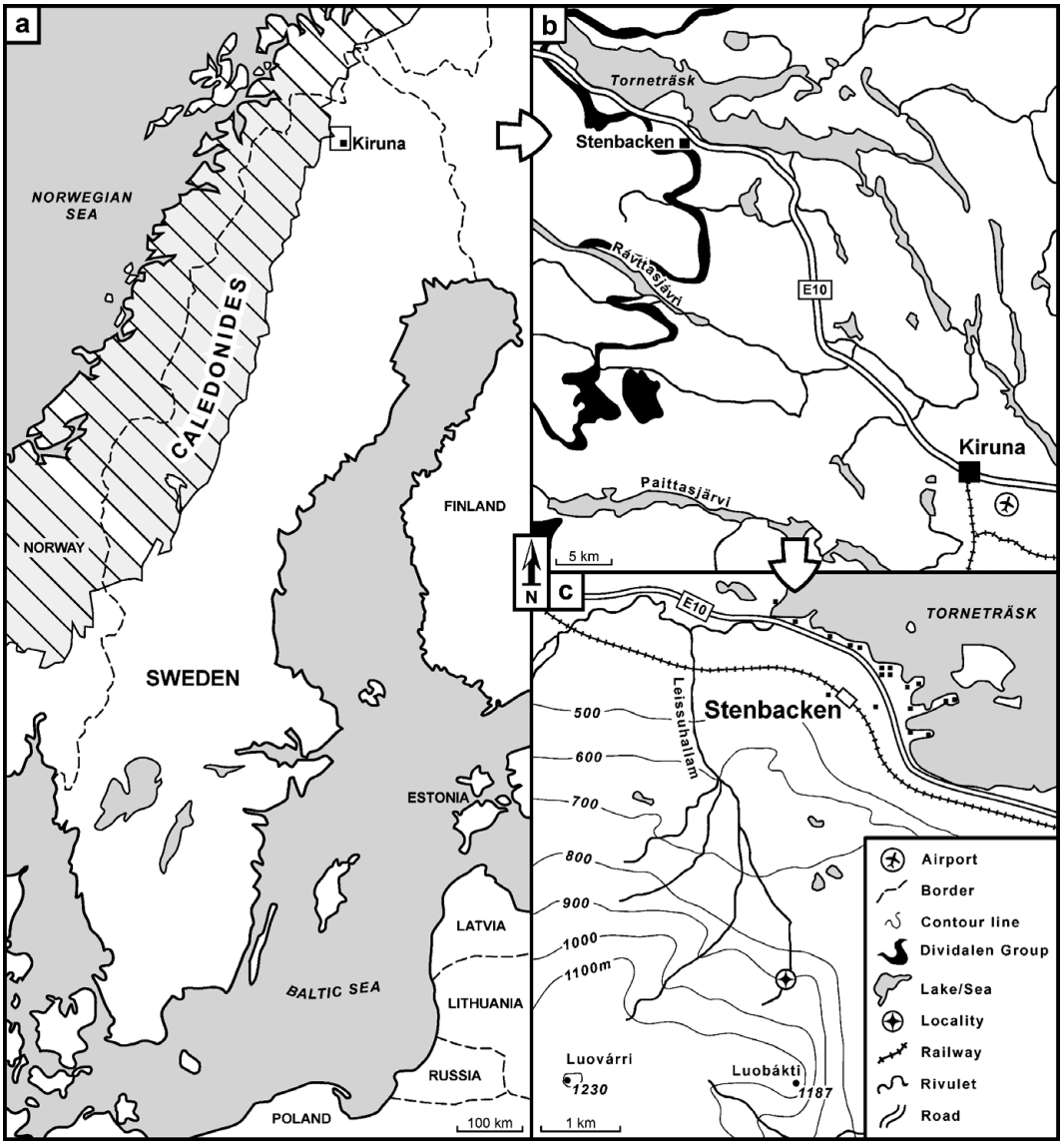

Figure 1. (a) Map of Sweden and surrounding areas showing the extent of the Caledonides. (b) Map of the Torneträsk area, northern Swedish Lapland, showing outcrop areas of the terminal Proterozoic?–Cambrian Dividalen Group. (c) Location of the Luobákti section south of Lake Torneträsk.

Upper sandstone, Red and green siltstone, Lower siltstone and the Lower sandstone members. The Torneträsk Formation is generally poorly fossiliferous and the precise age of the included members is not known. Trilobites from the top of the formation indicate a late early Cambrian age (Moberg, 1908; Ahlberg, 1980*a*, 1980*b*, 1985), and the presence of *Sabellidites* sp. (a problematic tubular organic fossil) and trace fossils, such as *Treptichnus pedum* (Banks, 1970) and *Kullingia concentrica* Glaessner *in* Føyn & Glaessner, 1979, in the Lower siltstone member suggest a position near the base of the Cambrian (Jensen & Grant, 1998; Jensen *et al*. 2002; cf. Vidal & Moczydłowska, 1996). Recent sequence stratigraphical studies indicate that the Red and green siltstone and at least the lower to middle part of the Upper sandstone member can be assigned to the *Schmidtiellus mickwitzi* Assemblage Zone (Fig. 2; A. T. Nielsen, Copenhagen, pers. comm. 2006).

The Dividalen Group is well exposed south of Lake Torneträsk, for instance, along the northern slope of Mount Luobákti (also known as Luopahta or Luopakte), *c*. 4 km south of Stenbacken railway station (Fig. 1). At Luobákti, the lower *c*. 112 m comprise the Torneträsk Formation and consist of sandstones alternating with siltstone- and shale-dominated units, and subordinate limestone and conglomerate beds (Fig. 2), representing fluvial and shallow marine tidal and storm-influenced environments (Kulling, 1964; Thelander, 1982). The succeeding Alum Shale Formation is unfossiliferous and possibly of middle Cambrian age. The material described herein was collected by PC from a bioclastic limestone forming the top of the

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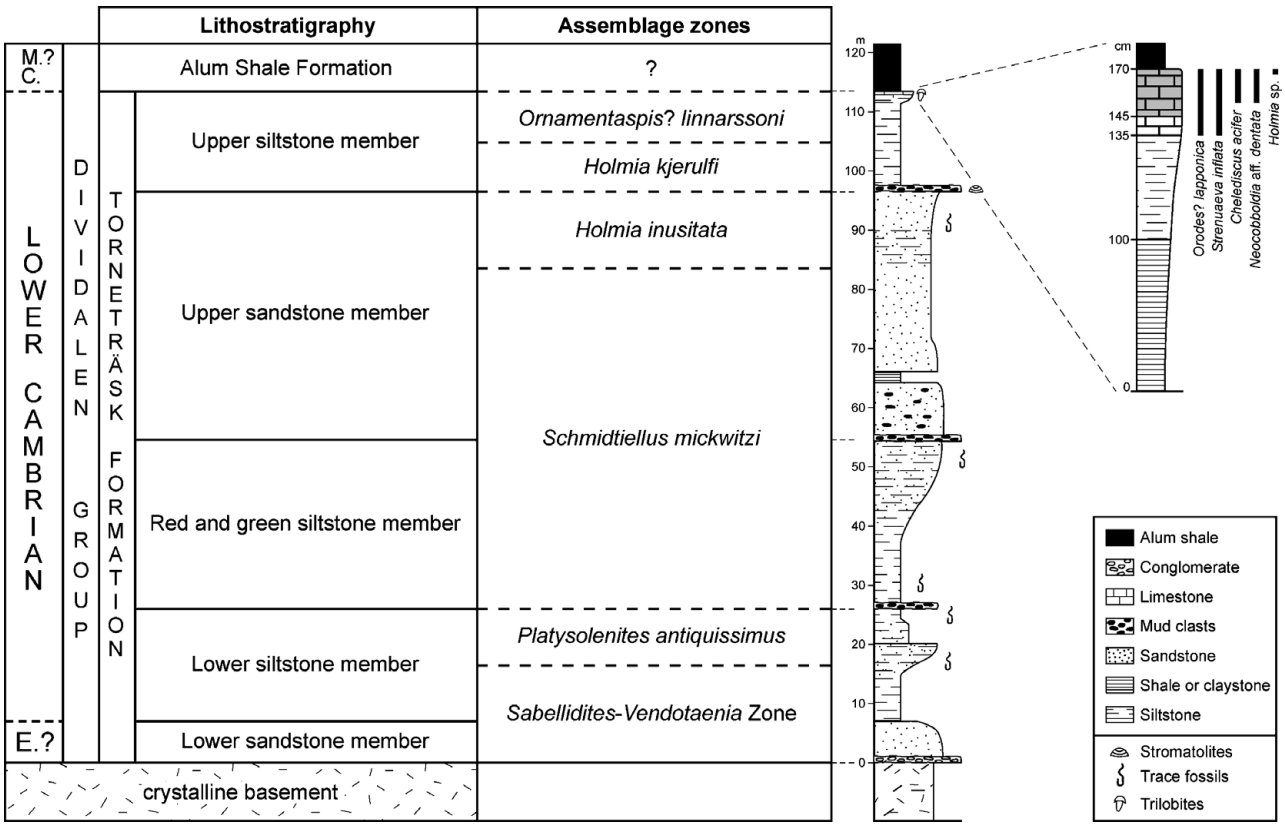

Figure 2. Lithological succession, stratigraphy and occurrences of fossils in the Luobákti section. Compiled mainly from Moberg (1908), Ahlberg (1985), Jensen & Grant (1998) and A. T. Nielsen, Copenhagen, pers. comm. 2006. M. C. – middle Cambrian; E. – Ediacaran.

Torneträsk Formation in a ravine at the northern flank of Luobákti (layer 23 in profile II of Moberg, 1908).

3. Faunal composition and preservation

All fossils were collected from the uppermost limestone in the Luobákti section (Fig. 2). The limestone is dense and dark grey to black in colour (for details, see Hadding, 1958). It contains a fauna dominated by trilobites, followed by phosphatic-shelled brachiopods, for instance, *Glyptias* cf. *favosa* (Linnarsson, 1869) and *Lingulella*? sp. Other faunal elements include rare helcionellid molluscs and the bradoriid *Indiana* sp. Five trilobite taxa (Fig. 4), *Chelediscus acifer*, *Holmia* sp., *Neocobboldia* aff. *dentata*, *Orodes*? *lapponica* (Ahlberg, 1980*a*) and *Strenuaeva inflata* Ahlberg & Bergström, 1978, were collected from the upper, darker, part of the limestone. *Orodes*? *lapponica* and *S. inflata* were also found in the lower part of the limestone. The trilobites are disarticulated and generally fragmentary, which may indicate that they have been subjected to post-mortem transport. The sclerites vary greatly in size, however, suggesting poor sorting and that the fauna represents an autochthonous fossil assemblage of moulted exuviae. Identification of fossils in the field was difficult and much of what is illustrated herein is the result of extensive preparation of bulk samples in the laboratory.

4. Biostratigraphy and correlation

The fossil record in the lower Cambrian of the Scandinavian Caledonides is scarce and the biostratigraphical resolution is inadequate. Five faunal zones are generally recognized, of which the upper four are defined by the occurrence of polymerid trilobites, in descending order, the *Ornamentaspis*? *linnarssoni*, *Holmia kjerulfi*, *H. inusitata* and the *Schmidtiellus mickwitzi* assemblage zones (e.g. Moczydłowska, 1991; Ebbestad, Ahlberg & Høyberget, 2003). The conventionally lowermost biostratigraphical unit, the *Platysolenites antiquissimus* Zone, is characterized by the occurrence of non-trilobite fossils, such as the enigmatic nominal species (see Føyn & Glaessner, 1979).

In contrast to the underlying zones, the two uppermost zones in the lower Cambrian of Scandinavia (the *H. kjerulfi* and *O.*? *linnarssoni* assemblage zones) contain diverse faunas, including, amongst others, a variety of olenellid and ellipsocephalid trilobites, eodiscoids, lingulate and other inarticulated brachiopods, molluscs, hyoliths and a few bradoriids (e.g. Kiær, 1917; Bergström & Ahlberg, 1981). The generic composition

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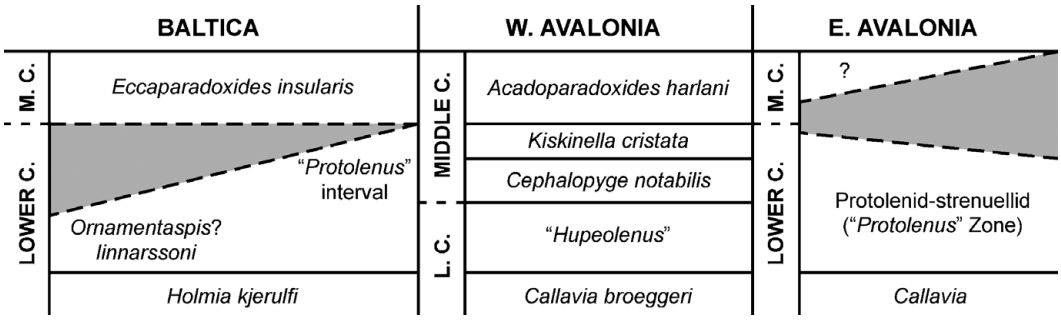

Figure 3. Correlation chart of the upper lower Cambrian and basal middle Cambrian for Baltica and western and eastern Avalonia. Modified after Geyer & Shergold (2000), Fletcher (2003), Fletcher *et al.* (2005) and Geyer (2005).

of the Luobákti trilobite fauna indicates a late early Cambrian age. The presence of a species of *Holmia* (Fig. 4s) at first sight might suggest that the fauna comes from the *H. kjerulfi* Assemblage Zone, but that genus ranges upwards into the *O.*? *linnarssoni* Assemblage Zone (Nikolaisen, 1986). The stratigraphical position of the fauna, at the top of the lower Cambrian and just below the Alum Shale Formation, indicates that it belongs to the *O.*? *linnarssoni* Assemblage Zone. This is supported by the common occurrence of shallow-water limestones in this zone (Kiær, 1917; Bergström & Ahlberg, 1981).

Intercontinental correlation within the lower Cambrian is hampered by the strongly provincial character of the trilobite faunas (e.g. Palmer, 1998). However, several genera and species of eodiscoids seem to have a wider geographical distribution than polymerid trilobites, and hence are important for long-distance correlations in the upper lower Cambrian (e.g. Robison *et al*. 1977; Fletcher, 2003; Geyer, 2005). The new collection of trilobites from Luobákti includes two eodiscoids previously unknown from Baltica, *Neocobboldia* aff. *dentata* and *Chelediscus acifer*, of which the latter provides a novel tie-line between lower Cambrian successions in Baltica and Avalonia.

Neocobboldia is relatively common in strata of Botomian age in Siberia and Mongolia, and has also been recorded from coeval successions in South China and Antarctica (e.g. Korobov, 1980; Repina, 1981; Palmer & Rowell, 1995; Korovnikov *et al*. 2002). Because the *Neocobboldia* species recovered from the Luobákti section cannot be adequately identified (see below), it is of little use for high-resolution correlation.

Chelediscus acifer is known from the middle Purley Shales ('*Protolenus*' Zone) of Warwickshire, England, where it is associated with, for example, *Serrodiscus ctenoa* Rushton, 1966, *Acidiscus theristes* Rushton, 1966, *Tannudiscus balanus* Rushton, 1966, and *Condylopyge amitina* Rushton, 1966. A similar *Condylopyge–Chelediscus–Tannudiscus* assemblage, including *C. acifer* and *T. balanus*, has been recorded from the upper Redland Cove Limestone Member of the lower to middle Brigus Formation (*Hupeolenus* Zone) in southeastern Newfoundland (Fletcher, 2003). The record of *C. acifer* from the Torneträsk area, northern Swedish Lapland, indicates that the *O.*? *linnarssoni* Assemblage Zone of Scandinavia can be correlated with the Protolenid–strenuellid Zone ('*Protolenus*' Zone) of eastern Avalonia (England) and the middle *Hupeolenus* Zone (*Tannudiscus balanus* Subzone of Fletcher, 2003) of western Avalonia (southeastern Newfoundland) (Fig. 3). Thus, the *O.*? *linnarssoni* Assemblage Zone is younger than strata yielding eodiscoid trilobites of the *Serrodiscus bellimarginatus–Triangulaspis annio–Hebediscus attleborensis* assemblage in Avalonia, Morocco, Taconic Laurentia and Siberia (see, e.g. Geyer & Palmer, 1995; Geyer, 2005), and older than the *Acidiscus–Cephalopyge* Assemblage 'Zone' (*Cephalopyge notabilis* Zone) of Avalonia and Morocco. This is in accordance with the recent correlation scheme of Geyer (2005, fig. 8).

5. Selected systematic palaeontology

All described and illustrated (LO) specimens are housed at the Department of Geology, Lund University, Sweden.

Suborder EODISCINA Kobayashi, 1939
Superfamily EODISCOIDEA Raymond, 1913
Family PAGETIIDAE Kobayashi, 1935
Genus *Neocobboldia* Rasetti, 1952

Type species. Cobboldia dentata Lermontova, 1940 (p. 120, plate 35, fig. 3a–e) from the lower Cambrian Botomian Stage (*Bergeroniellus micmacciformis*/*Erbiella* Zone) at the Lena River in Yakutia, Siberia.

Remarks. Species of *Neocobboldia* are characterized by an unfurrowed and nearly parallel-sided glabella, a wide (sag.), flat or concave preglabellar field, a usually narrow (sag. and exsag.) anterior border, a distinct palpebral furrow and a pygidium with prominent pleural furrows and a denticulate border (e.g. Palmer, 1968; Jell *in* Kaesler, 1997).

The genus is known from Siberia, Mongolia, China and possibly Antarctica. In Siberia and Mongolia, it appears near the base of the Botomian Stage and ranges upwards into the lower Toyonian Stage (e.g. Korobov,

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1980; Repina, 1981; Korovnikov *et al*. 2002). In China, it is known from the upper Nangaoan Stage of western Hunei and from coeval strata in southwestern Henan (Zhang *et al*. 1980; S. Peng, Nanjing, pers. comm. 2006). It is also known from Yichun in Heilongjiang (Duan & An, 2001). In Antarctica, only two incomplete pygidia of an indeterminate species are known from the Central Transantarctic Mountains (Palmer & Rowell, 1995).

Neocobboldia aff. *dentata* (Lermontova, 1940)
Figure 4a–j

Material. Sixty-seven cranidia, 59 pygidia, three thoracic tergites and two poorly preserved enrolled specimens. The cranidia range in length from 0.4 to 3.1 mm and the pygidia from 0.7 to 2.8 mm. The majority of the specimens are fragmentary.

Description of the adult. Cephalon semicircular, *c*. 1.1 times wider than long. Preglabellar field wide (sag.), depressed, separating anterior part of genae. Glabella tapering slightly forward, strongly convex (tr.), rounded in front, delimited laterally by wide and deep axial furrows. Occipital furrow distinct and curved backward medially. Occipital ring long (sag.) with rounded posterior margin. Genae inflated, tapering towards tip of glabella. Palpebral lobe long, defined adaxially by deep, narrow palpebral furrow. Slightly curved eye ridge extends from palpebral lobe inward across cheek towards anterolateral part of glabella.

Number of thoracic segments unknown. Pleural furrows broad, deep. Distal tips of pleura blunt.

Pygidium semicircular, smaller than cephalon, *c*. 1.5 times wider than long. Three pleural furrows, curved backwards, reaching border furrow. Pleural furrows wide, dividing pleural field into four pleural bands. Pygidial axis tapered backward, nearly reaching border furrow. Axis divided into three or four rings and a small terminal piece. Border wide, slightly expanding posteriorly, with denticulate margin.

Remarks. Several ontogenetic stages are represented. The smallest cranidium (0.4 mm long; Fig. 4c, h) is about 1.4 times wider than it is long and provided with a long, subcylindrical and 'hourglass-shaped' glabella, that is, constricted and slightly depressed in the middle. The preglabellar area is short (sag.) and largely occupied by the anterior border and border furrow. As size increases, the cranidium becomes proportionately narrower and the preglabellar field becomes longer (sag.). During growth there is also a change from an 'hourglass-shaped' glabella to a nearly parallel-sided glabella, tapering slightly forward.

The overall cephalic and pygidial features of this form most closely resemble those of *N. dentata*, except that it has a longer (sag.) occipital ring, a wider (sag.) anterior border and more pronounced eye ridges. The specific characteristics, however, cannot be adequately determined without knowledge of more and better preserved specimens.

Occurrence. Limestone at the top of the Torneträsk Formation (layer 23 in profile II of Moberg, 1908; probably *Ornamentaspis*? *linnarssoni* Assemblage Zone) in the Luobákti section, south of Lake Torneträsk, northern Swedish Lapland.

Family EODISCOIDAE Raymond, 1913
Genus *Chelediscus* Rushton, 1966

Type species. Cheledicus acifer Rushton, 1966 (pp. 19–21, text-figs 2b, 6, 7, pl. 2, figs 13–26) from the lower Cambrian Purley Shales ('*Protolenus*' Zone) of Warwickshire, England.

Remarks. Chelediscus is a distinctive genus that is known from upper lower Cambrian strata in England, Newfoundland, New York State and Russia (Rushton, 1966; Rasetti, 1967; Jell *in* Kaesler, 1997; Fletcher, 2003). It is characterized by, for example, a conical and bilobed glabella, a median preglabellar furrow, a pitted cephalic border furrow and two pairs of cephalic spines (one pair of genal spines and one pair of lateral spines; Rushton, 1966; Jell *in* Kaesler, 1997).

Chelediscus acifer Rushton, 1966
Figure 4k–p

1966 *Chelediscus acifer* sp. nov.; Rushton, pp. 19–21, pl. 2, figs 13–26, text-figs 2b, 6, 7 (described).
1992 *Chelediscus acifer*; Whittington, pl. 56, figs C–G (illustrated).
2003 *Chelediscus acifer* Rushton, 1966; Fletcher, pl. 1, figs 25, 26 (illustrated).
2005 *Chelediscus acifer* Rushton, 1966; Cotton & Fortey, p. 100, fig. 2A, B (discussed and illustrated).

Material. Sixteen cephala and 13 pygidia. The cephala range in length from 0.9 to 1.8 mm and the pygidia from 1.1 to 1.8 mm.

Remarks. The available material is disarticulated and generally fragmentary, but agrees in all essential features with Rushton's (1966) diagnosis and detailed description of the species. The lateral spines are generally not preserved in the cephala from Luobákti. The right lateral spine is, however, partially preserved in one cephalon (Fig. 4l). It is situated opposite the anterior glabellar lobe. The border furrow is provided with at least 20 pits. The pygidia have a wide and posteriorly tapered axis and a pair of distinct pleural furrows opposite the second axial ring.

The juvenile cephala shown in Figure 4m–o have a highly convex glabella lacking a distinct transglabellar furrow.

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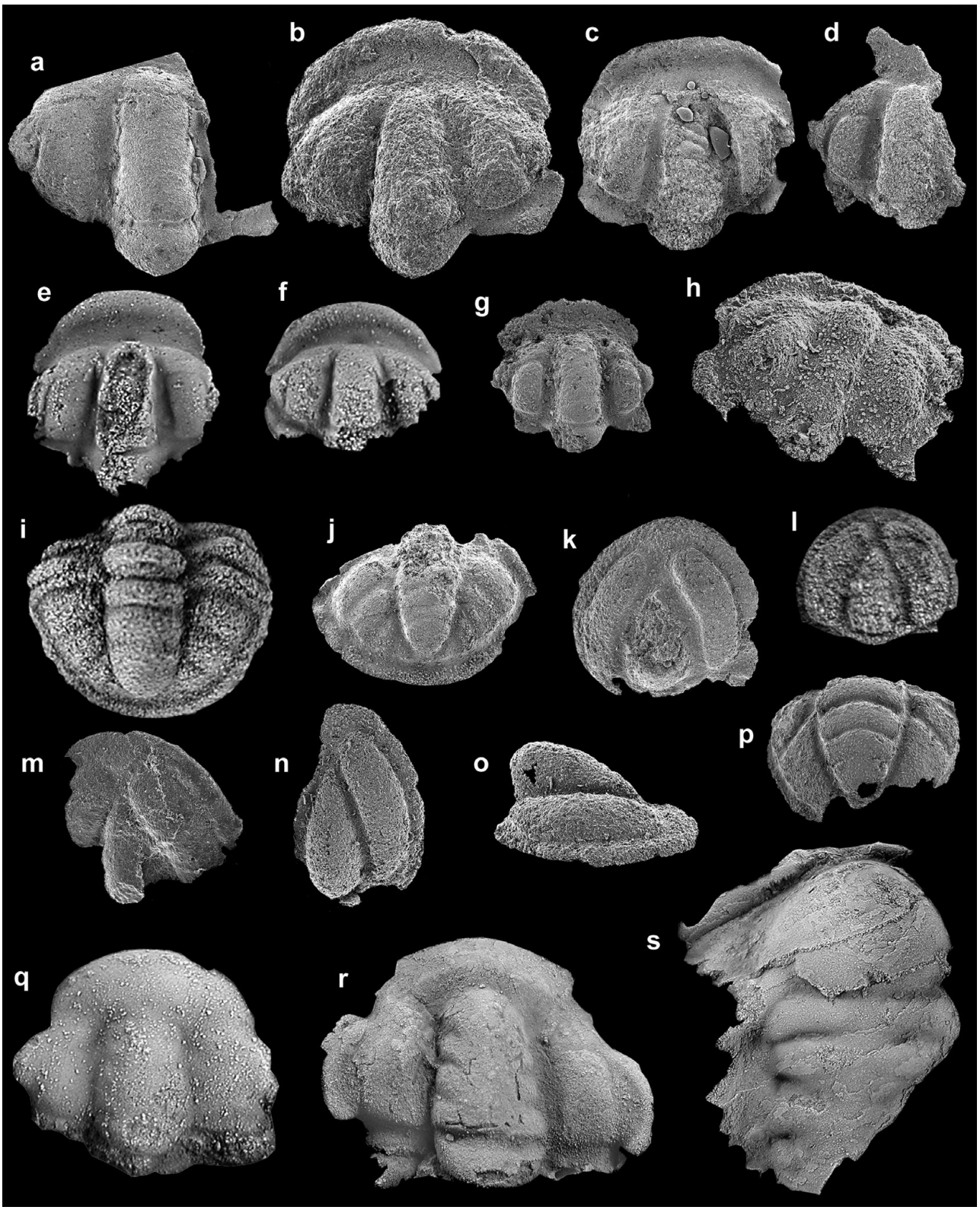

Figure 4. Trilobites from the top of the Torneträsk Formation in the Luobákti section, northern Sweden. All specimens except (e, f, i, l, q–s) are SEM-photographs of epoxy casts. (a–j) *Neocobboldia* aff. *dentata* (Lermontova, 1940). (a) Cranidium, ×15, LO9763t. (b) Cranidium, ×15, LO9764t. (c) Cranidium with a meraspid cranidium (see h) inside the broken part of the glabella, ×15, LO9765t. (d) Cranidium, ×15, LO9766t. (e) Cranidium, ×15, LO9767t. (f) Cranidium, ×15, LO9768t. (g) Cranidium, ×20, LO9769t. (h) Meraspid cranidium, oblique dorsal view, see also (c), ×85, LO9770t. (i) Pygidium, ×15, LO9771t. (j) Pygidium, ×20, LO9772t. (k–p) *Chelediscus acifer* Rushton, 1966. (k) Cephalon, ×20, LO9773t. (l) Cephalon, ×15, LO9774t. (m) Small cephalon, ×40, LO9775t. (n) Small cephalon, ×40, LO9776t. (o) Small cephalon, lateral view of (n), ×40, LO9776t. (p) Pygidium, ×20, LO9777t. (q) *Strenuaeva inflata* Ahlberg & Bergström, 1978, cranidium, ×11, LO9778t. (r) *Orodes*? *lapponica* (Ahlberg, 1980*a*), cranidium, ×6, LO9779t. (s) *Holmia* sp., incomplete cephalon, ×4, LO9780t.

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Occurrence. Limestone at the top of the Torneträsk Formation (layer 23 in profile II of Moberg, 1908; probably *Ornamentaspis*? *linnarssoni* Assemblage Zone) in the Luobákti section, south of Lake Torneträsk, northern Swedish Lapland. The species has also been reported from England (see above) and the lower to middle Brigus Formation (*Hupeolenus* Zone; *Tannudiscus balanus* Subzone) at Cape St Mary's, Newfoundland (Fletcher, 2003).

Suborder OLENELLINA Walcott, 1890
Superfamily OLENELLOIDEA Walcott, 1890
Family HOLMIIDAE Hupé, 1953
Genus *Holmia* Matthew, 1890
Holmia sp.
Figure 4s

Type species. Paradoxides kjerulfi Linnarsson, 1871 (pp. 790–1, pl. 16, figs 1–3) from the lower Cambrian Holmia Shale (*Holmia kjerulfi* Assemblage Zone) at Tømten in the Ringsaker district, Norway.

Remarks. The concept of *Holmia* adopted here is that of Palmer & Repina (1993), with slight modifications introduced by Ebbestad, Ahlberg & Høyberget (2003). As noted by, for example, Ahlberg & Bergström (1983), Ahlberg, Bergström & Johansson (1986) and Ebbestad, Ahlberg & Høyberget (2003), species of *Holmia* appear to be endemic to the Baltic Faunal Province, though, tentatively, a few species have been reported from Laurentia, Morocco and Siberia (see Palmer & Repina, 1993; Geyer & Palmer, 1995; but see also Hollingsworth, 2006).

Material. One slightly distorted but nearly complete glabella with an incomplete occipital ring and a partially preserved anterior cephalic border.

Description. Glabella (incl. occipital ring) nearly twice as long as wide, extending to anterior border. It is widest anteriorly across frontal lobe and slightly constricted at preoccipital furrow (S1). Frontal lobe 1.2 times wider than long, highly convex, steeply sloping anteriorly and laterally. Occipital ring (L0) and glabellar lobe L1 of equal length (exsag.) and slightly longer (exsag.) than L2 and L3. Occipital furrow (S0) and glabellar furrows S1 and S2 deepest adjacent to dorsal furrows, shallow or barely apparent across top of glabella. S0 almost transverse. S1 slightly longer (tr.) than S0, curved backward adaxially. S2 directed inward and slightly forward from dorsal furrow, then curved slightly backward adaxially. S3 transglabellar directed inward and forward from dorsal furrow, then curved abruptly inward and backward adaxially. Anterior border poorly preserved, seen only in front of right part of frontal glabellar lobe. It appears to be narrow (sag.) and almost flat.

Remarks. The anteriorly expanded glabella, with a broadly rounded and convex frontal lobe, the arrangement of the glabellar furrows and a conjoined S3 suggest that the material belongs to a species of *Holmia*. With the limited and fragmentary material at hand it is left under open nomenclature.

Occurrence. Limestone at the top of the Torneträsk Formation (layer 23 in profile II of Moberg, 1908; probably *Ornamentaspis*? *linnarssoni* Assemblage Zone) in the Luobákti section, south of Lake Torneträsk, northern Swedish Lapland.

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