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Cambrian (Series 3 – Furongian) conodonts from the Alum Shale Formation at Slemmestad, Oslo Region, Norway

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Nine samples from the Alum Shale of Slemmestad, Oslo Region, were processed for conodonts. The limestone-rich interval extending from the mid Cambrian Paradoxides paradoxissimus trilobite Zone to the Lower Ordovician Boeckaspis trilobite Zone yielded a sparse conodont fauna. The fauna is dominated by the protoconodont species Phakelodus elongatus (Zhang in An et al., 1983) and Phakelodus tenuis Müller, 1959, the paraconodont species Westergaardodina polymorpha Müller & Hinz, 1991, Westergaardodina ligula Müller & Hinz, 1991, Problematoconites perforatus Müller, 1959 and Trolmenia acies Müller & Hinz, 1991; the euconodont species Cordylodus proavus Müller, 1959 is present in the Acerocarina Superzone. The presence of the cosmopolitan Cordylodus proavus Müller, 1956 at Slemmestad provides an important tie for regional and international correlation.

Keywords: Conodonts, Alum shale, upper Cambrian, Oslo Region, Norway

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Introduction

Records of Cambrian conodonts are rare in Norway, but also an unexplored topic relative to other Cambrian faunal components such as trilobites. The first mention of Furongian (late Cambrian) euconodonts from the Oslo Region was by Bruton et al. (1982; i.e., named Cordylodus sp.). Later, Bruton et al. (1988) described a conodont fauna composed of Cordylodus proavus Müller, 1959 and Eoconodontus notchpeakensis Müller, 1969, both recorded from the Acerocarina ecorne trilobite Zone at the Närnaes section near Slemmestad in the Oslo Region (Fig. 1). As the investigated interval concentrated on the Cambrian–Ordovician boundary, it is uncertain whether the presence of C. proavus in the A. eocorne Zone represented the first occurrence of the conodont taxa in the succession or if the first occurrence should be present at a lower trilobite horizon.

In 2006 and 2013, nine samples, five to seven kilos each, were collected representing the interval from the Middle Cambrian, and from the Upper Cambrian in Slemmestad, with the purpose to investigate the conodont faunal succession. All samples contained conodonts, although with a very low yield.

This paper presents and expands our knowledge of the distribution of Cambrian conodonts in the Oslo District. In addition, the first appearance of Cordylodus proavus in the late Cambrian of the Oslo Region (Bruton et al., 1988) is confirmed and the significance and precise match with the existing trilobite zonation is outlined.


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Alum Shale Formation

The Alum Shale Formation (the type section: Gislövs- hammar-2 core, southern Sweden; Andersson et al., 1985; Bergström & Gee, 1985; Buchardt et al., 1997) consists of bituminous brown to black shale and mudstone with alternating limestone and siltstone beds. Bituminous limestone concretions (antraconites) occur as discontinuous to semicontinuous lenses throughout the entire formation (Martinsson, 1974). The Alum Shale Formation is uniformly developed and covered an area extending from western Norway to St. Petersburg in the east and from Poland in the south to Finnmark in northern Norway at its maximum extent (Bergström & Gee, 1985; Nielsen & Schovsbo, 2006). The high content of organic carbon suggests anoxic depositional conditions in a shallow-marine environment (Thickpenny, 1984, 1987; Buchardt et al., 1997) with sedimentation rates as low as 1 mm per 1000 years (Bjørlykke, 1974).

Due to the high content of carbon, the Alum Shale Formation is considered a good source rock (Buchardt et al., 1997); however, the deposits of the Alum Shale Formation in the Oslo Region have been exposed to high temperatures due to Permian intrusions and the source-rock potential is lost (Pedersen et al., 2006, 2007). The Alum Shale is also characterised by its high content of trace elements, mainly uranium and vanadium (Bergström & Gee, 1985).

The Alum Shale Formation is renowned for its rich fossil fauna of olenid, agnostoid and polymerid trilobites (Westergård, 1922, 1946, 1947; Henningsmoen, 1957; Ahlberg, 2003; Terfelt et al., 2008, 2011; Ahlberg & Terfelt, 2012; Nielsen et al., 2014). Trilobites are almost always absent in the shale, but present in the limestone nodules, sometimes in abundance and have been studied for many years (e.g., Brogger, 1882; Westergård, 1922, 1946; Henningsmoen, 1957). Substantial work with respect to systematic description of the trilobite fauna, which through several stages of amendments (Ahlberg & Terfelt, 2012; Høyberget & Bruton, 2012; Terfelt et al., 2011), has resulted in the current accepted scheme (Nielsen et al., 2014). The Alum Shale Formation comprises the strata from mid Cambrian (Series 3) to close to the top of the Lower Ordovician Tremadocian Series (Westergård, 1922, 1947; Høyberget & Bruton, 2012).

In Scania, Sweden, and the Oslo Region, Norway, the Upper Cambrian Acerocarina Superzone is completely developed, whereas most or parts of this upper superzone are missing in other regions of Baltoscandia (Nielsen et al., 2014; Terfelt et al., 2014).

The Oslo Region

The Oslo Region is located within a graben structure, formed during the Carboniferous–Permian extensional rifting (Neumann et al., 2004). The width varies from 35 to 65 km and is bordered by major normal fault zones to the east (Neumann et al., 2004). The graben of the Oslo Region extends over a distance of about 200 km to the north and south of Oslo starting in the south from Langesundsfjorden to the northernmost part of the Mjøsa district (Fig. 1). The Oslo Region is well known for its variety of rocks comprising Lower Palaeozoic and Upper Carboniferous sedimentary rocks and Upper Carboniferous to Permian igneous rocks.

Due to the graben structure, the Lower Palaeozoic deposits are extensively preserved in the Oslo Region. Following the rifting, these deposits were covered by erosional material from the surrounding horst area and by volcanic and magmatic rocks (Andersen, 1998). The Lower Palaeozoic strata in the northern part of the Oslo Graben were strongly deformed and folded during the Scandian phase of the Caledonian orogeny (Bruton et al., 2010), while the southern part is strongly affected by Permian magmatism.

In Norway, the Cambrian deposits occur locally as autochthonous strata or in successions within nappes of the Caledonian Lower Allochthon (Bergström & Gee, 1985). The Alum Shale has functioned as a basal thrust plane for the lower nappe units and is overall deformed and thermally altered (Bruton & Owen, 1982; Bergström & Gee, 1985; Gabrielsen et al., 2005).

Stratigraphy

The Cambrian–Ordovician succession of the Oslo Region is composed mainly of clastic sedimentary rocks (Bruton et al., 2010). The mid Cambrian to earliest Ordovician deposition in the region was characterised by calm conditions and the sedimentary rocks are assigned to the Alum Shale Formation and Bjørkåsholmen Formation (Owen et al., 1990).

The Upper Cambrian trilobite zonation for the Oslo Region (Henningsmoen, 1957; Høyberget & Bruton, 2012) and now updated by Nielsen et al. (2014) is used as a reference for correlation (Fig. 2).

The Alum Shale Formation directly overlies the basement or an unnamed arkose unit. It consists of shale, siltstone and prominent limestone nodules with a high concentration of organic carbon. The Alum Shale ranges in thickness from about twenty to almost a hundred metres (Owen et al., 1990) in the Oslo Region, and the antraconite concretions can be extremely fossiliferous, dominated by olenid trilobites (Henningsmoen, 1957; Høyberget & Bruton, 2012).

The Lower Ordovician Bjørkåsholmen Formation (formerly known as Ceratopyge shale and limestone)
The Alum Shale Formation is exposed at several localities in the Slemmestad area (Fig. 1).

**Localities**

The investigated sections (59.780–59.783N 10.495–10.499E; Fig. 1) are composed of Alum Shale, c. 100 m thick, which overlies an arkose, usually less than 0.5 m thick and is the oldest strata around Slemmestad (Spjeldnaes, 1955, 1962). Locally, the arkose rests on a conglomerate with rare clasts of limestone and sandy to conglomeratic carbonaceous sediments. In some places there is also a conglomerate above the arkose with rare clasts of quartzite and conglomerate. The combined thickness of the arkose and conglomerate may be up to 1.5 m.

Conformably overlies the Alum Shale Formation (Owen et al., 1990). The unit consists of dense to micritic limestone interbedded with shale; its thickness varies from 0.8 to 1.5 m (Ebbestad, 1999). The main faunal component is trilobites of the *Apatokephalus serratus* trilobite Zone (Ebbestad, 1999), and conodonts are referred to the *Paltodus deltifer* Zone. The unit is laterally extensive and present in much of Scandinavia.

**Geology of the Slemmestad area**

The Slemmestad area is located approximately 32 km southwest of Oslo. The sedimentary rocks are here preserved in the middle part of the Oslo Graben (Fig. 1), and the Lower Palaeozoic succession was strongly deformed and folded during the Caledonian orogeny. The Alum Shale Formation is exposed at several localities in the Slemmestad area (Fig. 1).

![Figure 1. (A, B) Location map with geographical details of the Oslo Region. (C) Location of sample collection sites. 1 – PEL13, 2 – GIBB13, 3 – KAM1; 2, 4–7. Map modified from Rasmussen et al., 2015.](image-url)
The Alum Shale succession extends from the \textit{Paradoxides paradoxissimus} trilobite zone (mid Cambrian) to the Lower Ordovician (Tremadocian) \textit{Boeckaspis} trilobite Zone.

\section*{Materials and methods}

\textit{Material.} – Nine samples, five to seven kilos each, collected from limestone-nodule rich levels with zonal trilobites (Fig. 2; Table 1).

\textit{Methods.} – The samples were dissolved in diluted acetic acid (c. 10\%) and five out of the nine samples yielded conodonts (Table 1). The acid-resistant residue from 63–500 \textmu{}m was separated using heavy liquid in order to extract the euconodonts. The conodonts were hand-picked under stereomicroscope and the SEM was used for the illustration of the conodonts.

\section*{Conodont biostratigraphy}

The Upper Cambrian trilobite zonation for the Oslo Region (Henningsmoen, 1957; Heyberget & Bruton, 2012) and now updated by Nielsen et al. (2014) is used as a reference for correlation (Fig. 2).

\section*{Conodont zones of northern Europe}

The present acknowledged Furongian euconodont zonation of Baltoscandia comprises the \textit{Proconodontus transitans}, \textit{Proconodontus muelleri}, \textit{Cordylopus andresi}, \textit{Cordylopus proavus}, \textit{C. caboti} and \textit{C. intermedius} zones (Kaljo et al., 1986; Mens et al., 1996; Szaniawski & Bengtson, 1998; Bagnoli & Stouge, 2014; Terfelt et al., 2014; Fig. 3). These zones – or parts of them – are described and established from Estonia (Kaljo et al., 1986), western Russia (Popov et al., 1989), Lithuania and western Russia (Artyushkov et al., 2000), northern Poland...
The Södre Sandby section in the Alum Shale Formation. As in Norway, *Cordylodus proavus* occurs together with *Eoconodontus notchpeakensis* and thus the interval in the Södre Sandby section is largely coeval with sample KAM6 from Slemmestad. The first record of *Cordylodus proavus* is safely placed within the *Westergaardia* Zone in Scania (Terfelt et al., 2014).

In Estonia and the St. Petersburg region, the faunal succession *Cordylodus? andresi* Viira & Sergeyeva, 1987 (in Viira et al., 1987), *Cordylodus primitivus* Bagnoli et al., 1987, *Cordylodus proavus* followed by *Cordylodus caboti* Bagnoli et al., 1987 and *C. lindstromi* have been recorded in sandy deposits of the Kallavere Formation. There, and from its lateral equivalent deposits in the St. Petersburg area (Kaljo et al., 1986; Viira et al., 1987; Popov et al., 1989; Mens et al., 1996; Artyushkov et al., 2000), *Cordylodus proavus* is associated with common *Eoconodontus notchpeakensis*.

The *Cordylodus proavus* Zone has regional importance because it is chosen to mark the base of the Pakerort Regional Series (Kaljo et al., 1986). This implies that the base of the Pakerort Regional Series corresponds to the base of – or close to – the *Westergaardia* trilobite Zone of the *Acerocarina* Superzone of Scania, Sweden, and the Oslo Region, Norway.

The conodont fauna from the Slemmestad section


In Scania, Sweden, the first record of the genus *Cordylodus* (listed as *Cordylodus cf. proavus*) is from

(Bednarczyk, 1979), Västergötland, central Sweden (Müller & Hinz, 1991; Szaniawski & Bengtson, 1998), Öland (Andres, 1981; Bagnoli & Stouge, 2014) and Skåne (Terfelt et al., 2014). The nominate taxa are recorded from the *Peltura scarabaeoides* trilobite Superzone (Szaniawski & Bengtson, 1998; Bagnoli & Stouge, 2014) with a possible extension into the lowermost *Acerocarina* Superzone (Andres, 1981; Nielsen et al., 2014). All these taxa, however, are older than the FO (First Occurrence) of *Cordylodus proavus* recorded by Bruton et al. (1982, 1988) and Terfelt et al. (2012) and in this study.

A hiatus is developed in central Sweden and the eastern Baltic area that covers the two or three lower trilobite zones of the *Acerocarina* Superzone (e.g., Martinsson, 1974; Mens & Pirrus, 1977; Szaniawski & Bengtson, 1998). Thus, the horizons with *Cordylodus proavus* recorded in Estonia and western Russia, the Oslo Region and in Scania, Sweden, are not represented in situ in central Sweden (Szaniawski & Bengtson, 1998; Löfgren & Viira, 2007). In addition, many records with *Cordylodus proavus* from Sweden and northern Germany are derived from loose blocks (Müller, 1959; Löfgren & Viira, 2007). The contained fauna recovered from the loose blocks commonly represents the *Cordylodus proavus* Zone, where *Cordylodus proavus* occurs together with *Eoconodontus notchpeakensis* in abundance (e.g., Löfgren & Viira, 2007). In addition, the species is also found in faunas where *Cordylodus proavus* occurs together with several younger species of *Cordylodus* (Löfgren, 1995).

**Table 1. Numerical distribution of conodont elements in the Slemmestad samples.**

<table>
<thead>
<tr>
<th>Species</th>
<th>GIBB13</th>
<th>KAM8</th>
<th>KAM2</th>
<th>PEL13</th>
<th>KAM1</th>
<th>KAM5</th>
<th>KAM4</th>
<th>KAM6</th>
<th>KAM7</th>
<th>Specimens total</th>
</tr>
</thead>
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<td>5</td>
<td>5</td>
<td>7</td>
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<td>5</td>
<td>5</td>
<td>5</td>
<td>3</td>
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<tr>
<td><em>Phakelodus elongatus</em></td>
<td>4</td>
<td>25</td>
<td></td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
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<td>32</td>
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<td><em>Phakelodus tenuis</em></td>
<td>1</td>
<td>12</td>
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<td></td>
<td></td>
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<td>15</td>
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<tr>
<td><em>Westergaardodina sp.</em></td>
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<td>4</td>
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<td></td>
<td></td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td><em>Westergaardodina polymorpha</em></td>
<td>2</td>
<td>7</td>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9</td>
<td></td>
</tr>
<tr>
<td><em>Problematoconites perforatus</em></td>
<td>1</td>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><em>Trolmenia acies</em></td>
<td>2</td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><em>Westergaardodina ligula</em></td>
<td>3</td>
<td></td>
<td></td>
<td>3</td>
<td></td>
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<tr>
<td><em>Cordylodus proavus</em></td>
<td>5</td>
<td>0</td>
<td>41</td>
<td>2</td>
<td>0</td>
<td>18</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>70</td>
</tr>
<tr>
<td>Unidentified (fragments)</td>
<td>45</td>
<td>1</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>46</td>
</tr>
</tbody>
</table>
Müller, 1959 and Troelsenia acies Müller & Hinz, 1991. The euconodonts are all recorded from the uppermost Acerocarina Superzone and are referred to Cordylodus proavus Müller, 1959.

Kaljo et al. (1986), Popov et al. (1989), Szaniawski & Bengtson (1998) and Bagnoli & Stouge (2014) introduced para- and euconodont biozones for the Upper Cambrian (Furongian) and Lower Ordovician, which is used here as reference (Figs. 2 & 3).

The species from Slemmestad are all long-ranging taxa. At present, our knowledge of the distribution of paraconodonts is not yet ready for biozonation or detailed correlation (e.g., Müller & Hinz, 1991; Bagnoli & Stouge, 2014). However, similar paraconodont associations have been reported previously from most of the Upper Cambrian deposits in central Sweden and on Öland (Müller & Hinz, 1991; Szaniawski & Bengtson, 1998; Bagnoli & Stouge, 2014; Terfelt et al., 2014).

Bruton et al. (1982) and Bruton et al. (1988) recorded Cordylodus proavus together with a low diverse euconodont faunal assemblage from the Nærsnes section, close to Slemmestad. These authors focused on the Cambrian–Ordovician system boundary and thus investigated the interval ranging from the Acerocarina eocorne Zone – the top zone of the Acerocarina Superzone – to the Lower Ordovician Boekaspis hirsuta Zone. The conodont fauna from the uppermost Acerocarina trilobite Superzone includes the important euconodont species Cordylodus proavus and Eoconodontus notchpeakensis, and the conodont fauna was referred to the Cordylodus proavus conodont Zone sensu Kaljo et al. (1986).

The following anthraconite horizon with Boekaspis hirsuta yielded Cordylodus proavus and Eoconodontus notchpeakensis extending from below but now occurring together with Cordylodus intermedius Furnish, 1938, Cordylodus lindstromi Druce & Jones, 1971 and Iapetognathus preaengensis Landing in Fortey et al., 1982.

This younger conodont fauna is here referred to the Cordylodus lindstromi conodont Zone of Kaljo et al. (1986). Bruton et al. (1988) and Cooper et al. (1998) recorded and described the Early Ordovician graptolite succession starting from Rhabdinopora praeparabola (Bruton et al., 1982) to Rhabdinopora parabola (Bulman, 1954) from the shale just above the Boekaspis-yielding limestone nodule.

The latest Cambrian low diverse fauna from the Slemmestad section with the appearance of Cordylodus proavus in sample KAM6 is referred to the Cordylodus proavus Zone (sensu Kaljo et al., 1986; i.e., Furongian Series, uppermost Cambrian; Fig. 3). Unfortunately, the investigated sample KAM7 from the Boekaspis hirsuta trilobite Zone was barren and thus no new data can be added to those already given by Bruton et al. (1988) from this trilobite zone.

<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>SERIES</th>
<th>STAGES</th>
<th>FORMATION</th>
<th>TRILLOBITE SUPERZONES AND ZONES</th>
<th>CONODONT ZONES</th>
<th>ESTONIA</th>
<th>Baltoscandia</th>
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</thead>
<tbody>
<tr>
<td>CAMBRIAN</td>
<td>Furongian</td>
<td>Stage 10</td>
<td>Alum Shale</td>
<td>Triagnostus holmi</td>
<td>Acerocarina scaniaca</td>
<td>not recorded</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>Cordylodus proavus</td>
<td>not recorded</td>
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</table>

Figure 3. Correlation of the Slemmestad euconodont fauna. Conodont zones of the Baltoscadian Region (from Kaljo et al., 1986; Viira et al., 1987; Mens et al., 1993; Szaniawski & Bengtson, 1998; Bagnoli & Stouge, 2014). The trilobite zones are from Nielsen et al. (2014).
Conclusions

The conodont fauna recorded from the Slemmestad section is composed of proto-, para- and euconodonts. The protoconodont succession begins in the lowermost sample, GIBB13, correlating with the Paradoxides paradoxissimus trilobite Superzone; it includes the species given in Table 1 and Fig. 3. Phakelodus tenuis has its upper range in sample KAM5, correlating to the Peltura Superzone, while Phakelodus elongatus is present in all the conodont-bearing samples (Fig. 3). In Scandinavia, Phakelodus tenuis and Phakelodus elongatus have been reported from older and age-equivalent deposits (Miller, 1984; Müller & Hinz, 1991; Bagnoli & Stouge, 2014; Terfelt et al., 2014).

The paraconodonts are present in three of the five conodont-bearing samples (Fig. 3; Table 1). The succession of the paraconodonts begins in sample KAM2 with one unidentifiable species of the genus Westergaardodina in the Parabolina Superzone. Westergaardodina polymorpha is present in samples PEL13 and KAM5, both representing the Peltura Superzone. The conodont fauna changes in sample KAM5 with a diverse fauna compared with the other samples (Fig. 3; Table 1). Here, Westergaardodina ligula, Trolmenia acies and Problematoconites perforatus are present. The paraconodont succession has its last occurrence in sample KAM5 within the Peltura Superzone, but the paraconodont species are long-ranging taxa and are reported from older as well as age-coeval deposits from Sweden (see Müller & Hinz, 1991; Bagnoli & Stouge, 2014; Terfelt et al., 2014).

The sample KAM6 yielded Cordylodus proavus, a species that is ranging from the Westergaardia to the Acerocare trilobite zones of the Acerocarinina Superzone. Thus, the investigated sample of the Cordylodus proavus Zone may be referred to the Westergaardia trilobite Zone and/or the Acerocare ecorne trilobite Zone, as previously reported from the Oslo Region (i.e., Bruton et al., 1988).

The current study has provided new information on the distribution of conodonts in the Oslo Region and supported previous studies, as well as filling in faunal gaps in the Slemmestad section.

Taxonomical remarks

The small number of specimens recorded in this study does not provide any new significant information on the taxa already fully described by Müller & Hinz (1991) and Bagnoli & Stouge (2014); however, a few remarks on the material are presented here.
Remarks. – The Slemmestad material consists of slender, gently recurved, simple cone elements, which are rounded anteriorly and posteriorly; the cross-section of the base is oval.

Material. – 47 specimens.

Occurrence. – GIBB13 (1 specimen), KAM2 (12 specimens), PEL13 (32 specimens), KAM5 (2 specimens), Alum Shale Formation, Slemmestad, Norway.

Stratigraphic distribution. – Paradoxides paradoxissimus Superzone to Acerocarina Superzone, mid to upper Furongian Series, Cambrian.

Phylum CHORDATA Bateson, 1886
Class CONODONTA Pander, 1856
[Class CONODONTA Eichenberg, 1930]
Order PARACONODONTIDA Müller, 1962
Genus Problematoconites Müller, 1959
Type species. – Problematoconites perforata Müller, 1959.

Problematoconites perforatus Müller, 1959

Figure 4. (A, D, F, H, J–M) Phakelodus elongatus Zhang in An et al., 1983. (A) PMO 221.739/40, lateral view; sample KAM5. (D) PMO 221.748/1, lateral view; sample PEL13. (F) PMO 221.737/5, lateral view; sample KAM2. (H) PMO 221.746/56, incomplete cluster; sample KAM2. (J) PMO 221.737/5, lateral view; sample KAM6. (K) PMO 221.746/22, postero-lateral view; sample KAM2. (L) PMO 221.742/25, lateral view; sample PEL13. (M) PMO 221.746/19, lateral view; sample KAM2. (B, C, E, G, I) Phakelodus tenuis (Müller, 1959). (B) PMO 221.742/40, lateral view; sample PEL13. (C) PMO 221.742/44, lateral view; sample PEL13. (E) PMO 221.737/5, posterior lateral view; sample KAM6. (G) PMO 221.746/17, incomplete cluster; sample KAM2. (I) PMO 221.742/63, lateral view; sample PEL13. Scalebar represents 500 µm.
1959 *Problematoconites perforata* n. sp. Müller, p. 471, pl. 15, fig. 17.


2014 *Problematoconites perforatus* Müller, 1959 – Bagnoli & Stouge, fig. 8K.

**Remarks.** – The Slemmestad specimens are recurved with a large basal opening, and rounded tip. The cross section is oval at the base.

**Material.** – 4 specimens.
Occurrence. – KAM5 (4 specimens), Alum Shale Formation, Slemmestad, Norway.

Stratigraphic distribution. – Peltura Superzone, Stage 10, Furongian Series, Cambrian.

Genus Trolmenia Müller & Hinz, 1991

Type species. – Trolmenia acies Müller & Hinz, 1991.

Trolmenia acies Müller & Hinz, 1991

Fig. 5E

1991 Trolmenia acies n. sp. Müller & Hinz, pp. 39, 40, pl. 26, 1–9, fig. 16A–C.
2014 Trolmenia acies Müller & Hinz, 1991 – Bagnoli & Stouge, fig. 8S, T.

Material. – 1 specimen.

Occurrence. – KAM5 (1 specimen), Alum Shale Formation, Slemmestad, Norway.

Stratigraphic distribution. – Peltura Superzone, Stage 10, Furongian Series, Cambrian.

Genus Westergaardodina Müller, 1959

Type species. – Westergaardodina bicuspicata Müller, 1959.

Westergaardodina ligula Müller & Hinz, 1991

Fig. 5D, E

1991 Westergaardodina ligula n. sp. Müller & Hinz, p. 46 (cum syn.), pl. 28, figs. 1–14.
2014 Westergaardodina ligula Müller & Hinz, 1991 – Bagnoli & Stouge, fig. 9R.

Remarks. – These tricuspidate elements have a small median projection. The anterior side is strongly convex. The posterior side is deeply excavated giving it a spoon-like appearance.

Material. – 3 specimens.

Occurrence. – KAM5 (3 specimens), Alum Shale Formation, Slemmestad, Norway.

Stratigraphic distribution. – Peltura Superzone, Stage 10, Furongian Series, Cambrian.

Westergaardodina polymorpha Müller & Hinz, 1991

Fig. 6A–C, F–I

1991 Westergaardodina polymorpha n. sp. Müller & Hinz, pp. 48, 49 (cum syn.), pl. 31, figs. 1–21.
1998 Westergaardodina polymorpha Müller & Hinz, 1991 – Müller & Hinz, fig. 15.1–15.3.
2014 Westergaardodina polymorpha Müller & Hinz, 1991 – Bagnoli & Stouge, fig. 9S–V.

Remarks. – Gently recurved bicuspidate elements with a much larger posterior side than anterior side. The profile is rather flat and the median projection is very small, or absent. The lateral projections diverge increasingly during growth. The posterior side is commonly enlarged in the basal part.

Material. – 9 specimens.

Occurrence. – PEL13 (2 specimens), KAM5 (7 specimens), Alum Shale Formation, Slemmestad, Norway.

Stratigraphic distribution. – Peltura Superzone, Stage 10, Furongian Series, Cambrian.

Order CONODONTOPHORA Eichenberg, 1930
Superfamily CORDYLODONTACEA Lindström, 1970
Family CORDYLODONTIDAE Lindström, 1970

Genus Cordylodus Pander, 1856

Type species. – Cordylodus angulatus Pander, 1856.

Cordylodus proavus Müller, 1959

Fig. 6F–H

1959 Cordylodus proavus Müller, p. 448, pl. 15, figs. 11, 12, 18; fig. 3B.
1974 Cordylodus angulatus Pander, 1856 – van Wamel, pp. 58, 59, pl. 1, fig. 5 (only).
1987 Cordylodus proavus Müller, 1959 – Viira et al., pp. 149–151, pl. 2, figs. 1–6, pl. 3, figs. 3, 8, 12; text-fig. 2: 1–3, 6–9, 19–21, 23–29; text-fig. 3: 3, 6, 7, 10, 11, 16, 17, 22; text-fig. 4: 6–27.
1996 Cordylodus proavus Müller, 1959 – Mens et al., pl. 2, figs. 1–3, non pl. 1, fig. 9 (= Cordylodus primitivus Bagnoli et al., 1987).
1998 Cordylodus proavus Müller, 1959 – Andres, p. 129, figs. 26–34, pl. 13, figs. 1, 2 (= Cordylodus andresi Viira et al. in Kaljo et al., 1986).
1998 Cordylodus proavus Müller, 1959 – Bruton et al., fig. 4f.
Cordylodus proavus Müller, 1959 – Terfelt et al., figs. 5A–E, 7T, U.

**Comments to synonymy** – The specimens illustrated by Olgun (1987) did not show the diagnostic basal cavity and the specimens are tentatively referred to this species. The specimens marked with a question mark probably represent *Cordylodus primitivus* Bagnoli et al., 1987. *Cordylodus proavus* sensu Andres is *Cordylodus cf. C. andresi* (see Szaniawski & Bengtson, 1998, p. 16).

**Remarks.** – The dolobrate elements are recurved; the deep basal cavity extends up to about 1/3 of the length of the cusp. The denticles and the cusp above the tip of the basal cavity are albid. The material includes a rounded, compressed and twisted element.

**Material.** – 3 specimens.

**Occurrence.** – KAM6 (3 specimens), Alum Shale Formation, Slemmestad, Norway.

**Stratigraphic distribution.** – Acerocarina Superzone, Stage 10, Furongian Series, Cambrian.

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