TÜBİTAK

Turkish Journal of Earth Sciences

http://journals.tubitak.gov.tr/earth/

Research Article

Turkish J Earth Sci
(2016) 25: 201-226

doi:10.3906/yer-1505-18

Notes on beyrichiacean ostracodes from the Early Devonian of NW Turkey and their palaeobiogeographical relations

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Received: 22.05.2015 • **Accepted/Published Online:** 15.02.2016 • **Final Version:** 05.04.2016

Abstract: Recently found materials of large beyrichiacean ostracodes from the Early Devonian of the Darlık, Korucuköy, and Kabalakdere sections in NW Anatolia stimulated the restudy of ostracode collections from the İstanbul area, including the Toula collection (GBA Vienna) and Endriss collection (previously in GPI Marburg and currently in SMF Frankfurt), and their biostratigraphical and palaeogeographical significance. The species *Gibba kayseri*, *Gibba schmidti*, *Zygobeyrichia roemeri*, *Zygobeyrichia subcylindrica*, and *Zygobeyrichia onusta* are documented and beyrichiid gen. et sp. indet. is described. There are great similarities with ostracode faunas from Early Devonian shallow-water sediments of Europe and North Africa (in Germany from the Rhenish Schiefergebirge to Thuringia, northern France, Spain, Poland, Bohemia, Podolia, Moravia, and North-West Africa). Therefore, this distribution questions the presence of a deeper and wider Rheic Ocean, which would be difficult for shallow-water benthic organisms to cross.

Key words: Ostracoda, Early Devonian, Anatolia, taxonomy, palaeobiogeography

1. Introduction

The first Devonian beyrichiacean, a poorly preserved ostracode, was cited by Roemer (1863) from black shales from the Arnaut Köy/Bosphorus area (collection Dumont) and later determined by Jones (1890) as *Beyrichia devonica*. De Verneuil (1864) dated the locality of Roemer (1863) as Early Devonian. Kayser (1899) described external and internal moulds and one calcareous valve as *Beyrichia roemeri* n.sp. from the Early Devonian of NW Turkey.

Hüffner (1918) published new palaeontological data on the Devonian from the Bosphorus area, concentrating on the collections of Endriss, which was bought by the Geological Institute of Marburg University (now deposited with numbers SMF Mbg. in the Senckenberg Museum Frankfurt). Hüffner (1918) did not figure ostracodes, but he accepted the determination of internal moulds in the Endriss collection as *Beyrichia roemeri* Kayser.

Paeckelmann (1938) published many occurrences of *Beyrichia roemeri* from different Turkish localities in the Early Devonian "Pendik Schichten", including the collection of Endriss (Paeckelmann, 1938).

During recent studies within joint projects (DEVEC-TR) supported by TÜBİTAK/Turkey (Project No. 104Y218), BMBF/Germany (Project No. TUR04/009), IGCP-499, and Çukurova University (Project No. MMF2012BAP4), internal and external moulds of large beyrichiacean ostracodes have been found in early Devonian units in the Zonguldak/Çamdağ and İstanbul areas. Large beyrichiacean genera like *Gibba* and *Zygobeyrichia* are widespread in shallow-water and high-energy environments in the European Early Devonian. The ostracodes were collected from two sections (Korucuköy and Darlık) in the Kartal Formation and from one section (Kabalakdere) in the Fındıklı Formation. Brachiopods, tentaculites, corals, and trilobites have also been found in the same formations.

The aim of this research is to give an overview of the beyrichiacean ostracodes and to analyse their records from the İstanbul region, north-western Turkey, to help establish international biostratigraphical and palaeogeographical correlations.

2. Geological setting

The study area is located in the Kocaeli Peninsula of the Pontides, NW Anatolia (Figure 1). The Pontides consist of the Strandja Massif, the İstanbul Zone, and the Sakarya Zone, which amalgamated during Cretaceous time (Okay and Tüysüz, 1999; Okay, 2008). The tectonic and stratigraphic features of the İstanbul Zone and Zonguldak area were investigated by different authors (Haas, 1968;

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Figure 1. Map of the studied areas and old collections and new beyrichiacean localities (modified from Yalçın and Yılmaz, 2010).

Kaya, 1973; Aydın et al., 1987; Okay, 1989; Derman and Özçelik, 1993; Göncüoğlu et al., 1997, 2003; Görür et al., 1997; Göncüoğlu and Kozur, 1999; Gedik and Önalan, 2001; Gedik et al., 2005; Yanev et al., 2006; Boncheva et al., 2009; Yalçın and Yılmaz, 2010; Özgül, 2012; Yılmaz et al., 2015). The thick Palaeozoic sedimentary successions of the Pontides contain unmetamorphosed Devonian rocks. Sedimentary sequences characterise the Devonian in the İstanbul area in the west and in the Çamdağ-Zonguldak area in the east of the Kocaeli Peninsula. The studied

Early Devonian units belong to the Kartal Formation in the İstanbul area (Tarabya, Kanlıca, Kartal, Pendik, Tuzla, and Şile) and the Fındıklı Formation in the Çamdağ-Zonguldak area.

Different authors referred to the Kartal Formation under different names: "Intermediare fazies" by Paeckelmann (1938); "Grauwackenschiefer" by Okay (1947); "Kartal-Schichten" by Haas (1968); "Kartal Formation" by Kaya (1973), Önalan (1987–1988), and Gedik et al. (2005); and "Kartal Member" by Özgül (2012). It consists of yellowish brown, grey, thin- to medium-bedded, sandy siltstones and shales and is very rich in brachiopods, corals, trilobites, cephalopods, and ostracodes. Its thickness varies between 600 and 800 m.

The Fındıklı Formation was named by Aydın et al. (1987) and consists of calcareous siltstones and mudstones, alternating with blue, grey, medium-bedded, fossiliferous limestones. The thickness of the Fındıklı Formation is between 300 and 400 m. The upper part of the Fındıklı Formation is discussed in this study.

3. Material

3.1. Beyrichiacean localities of previous collections

The ostracodes described by Kayser (collection of Prof. Toula, GBA Vienna) and Paeckelmann (Museum of Palaeontology in Berlin) and the unpublished material of the Endriss collection (SMF Frankfurt) came mostly from the İstanbul area but without details of the section or stratigraphic level.

Beyrichiacean ostracodes are deposited in the cited collections with different labels such as Pendik/Bosporus Dr. Endriss 1908; Tuzla/Bosporus Dr. Endriss 1908; Yakadjik, Endriss 1908 (= Yakacik); Therapia am Bosporus, coll. Endriss (= Tarabya); Kanlydscha, Toula 1895 (Kanlydja = Kanlica); and Pendik-Kartal, Toula 1895.

3.2. New Beyrichiacean localities in the İstanbul-Şile and Zonguldak-Çamdağ areas

3.2.1. Darlık Section

The section studied is located in the Darlık Reservoir in the İstanbul region (NW Turkey). The upper part of the Kartal Formation, containing yellowish green mud- and siltstones and fine-grained sandstones, was investigated in the first 43 m from the Darlık Section and 11 samples were collected.

Zygobeyrichia roemeri (Kayser, 1899) was found in samples from 0 m to 25 m and *Gibba schmidti* (Eichenberg, 1931) in samples from 0 to 33 m (Figure 2).

3.2.2. Korucuköy Section

Greenish-grey, yellowish-green, blue-grey calcareous shales and siltstones of the Kartal Formation have been observed in the Korucuköy section in the Şile-İstanbul area. The section is located to the north of Korucu village, at about 8 km to the south-east of Şile on the Black Sea coast. The total thickness of the section is 235 m. Twenty-nine samples were collected in this section and "*Zygobeyrichia*" *subcylindrica*, *Zygobeyrichia roemeri*, *Gibba schmidti*, and *Zygobeyrichia* sp. were determined in samples between 26 and 115 m of the Kartal Formation (Figure 3).

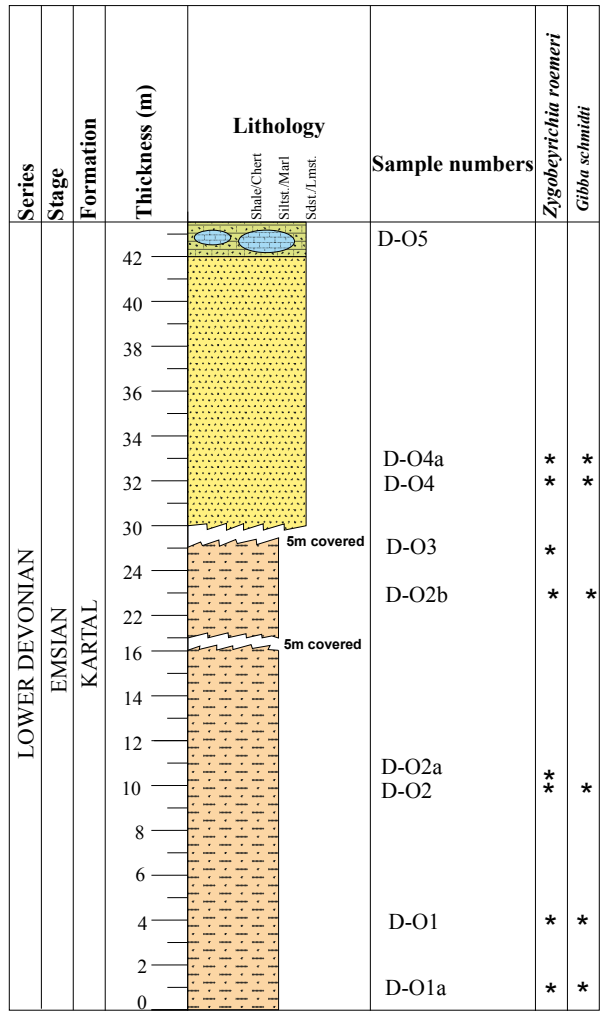


Figure 2. The distribution of beyrichiacean ostracodes in the Darlık section.

3.2.3. Kabalakdere Section

The Devonian Fındıklı Formation was studied in the Kabalakdere Section in the western Pontides in the Çamdağ area, Zonguldak (GPS coordinates: bottom: 40°58′01.9″N, 30°46′05.6″E). This formation consists of an alternation of shales, siltstones, and cross-bedded and laminated sandstones at the base of the Kabalakdere section. The upper part of this section is represented by calcareous siltstones, which alternate with some fossiliferous limestones. Twenty-nine samples were examined for

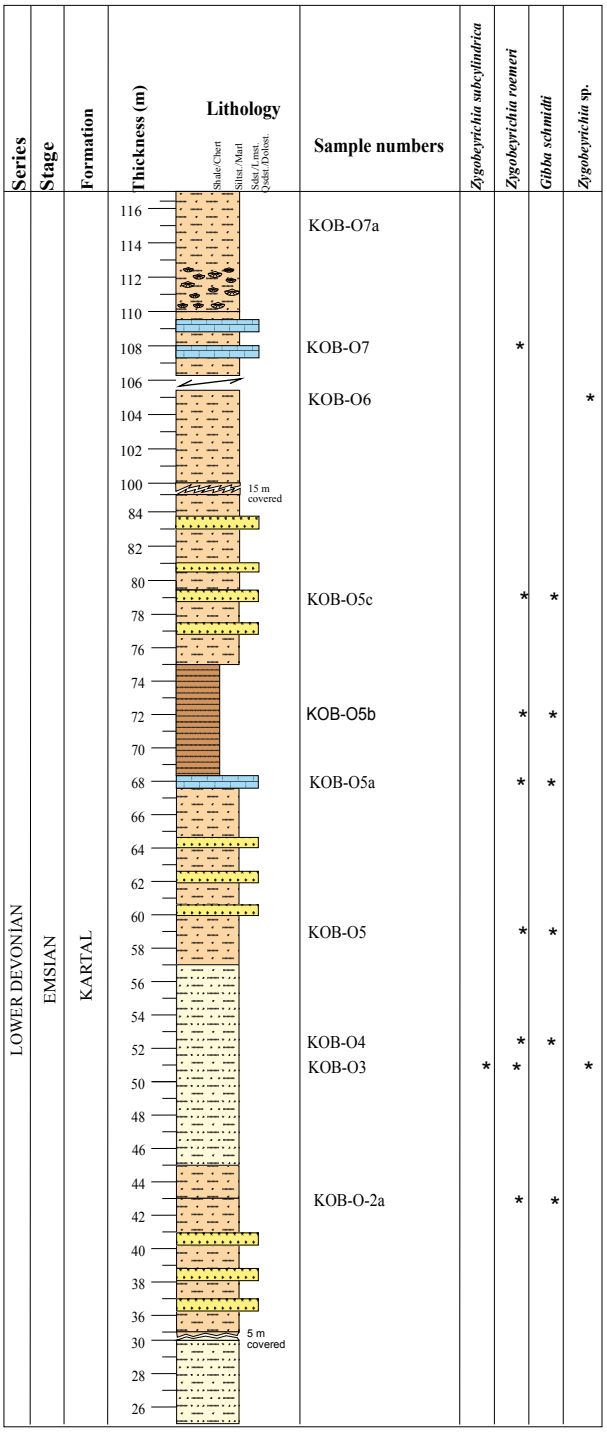


Figure 3. The distribution of beyrichiacean ostracodes in the Korucuköy section.

ostracodes. *Zygobeyrichia* sp. aff. *Z. onusta*, *Zygobeyrichia roemeri*, *Gibba* sp., and beyrichiid gen. et sp. indet. have been determined in samples from the Kabalakdere Section (Figure 4). *Gibba*? *kayseri* was found for the first time, in samples Ka13-O4 and Ka13-O5, which were dated on brachiopods as Early Lochkovian, which is comparable with the Gedinnian of the Rhenish Schiefergebirge/ Germany of the lowermost Early Devonian.

3.3. Beyrichiacean ostracodes and their preservation

Large Beyrichiacean ostracodes are widespread in Silurian and Early Devonian shallow-water deposits. Since the detailed study of the well-preserved Silurian beyrichiacean ostracodes from Gotland/Sweden by Martinsson (e.g., 1962, 1965) they are very important for biostratigraphy and correlation purposes, especially in shallow-water limestone or marl sequences.

In contrast to those well-preserved Silurian ostracodes, the Early Devonian beyrichiacean ostracodes of Europe are mainly preserved as external and internal moulds of mainly disarticulated carapaces, rarely of articulated ones. They occur in shales and sandstones. The details of their external shell morphologies are often poorly preserved (Groos-Uffenorde, 1983).

The large beyrichiacean ostracodes from the Early Devonian of north-western Turkey are also mostly preserved as internal and external moulds. Often specimens with distinct dimorphic structures occur in the same sample: heteromorphs with the crumina and tecnomorphs with an alate structure clearly sticking out of the valve (e.g., *Gibba*), and those with less remarkable dimorphic structures (e.g., *Zygobeyrichia*) (Figure 5). Their lobation is clearly visible on internal and external moulds. The ornamentations, such as tubercles, reticulation, and diverse ridges, are only preserved on external moulds, which are very rare.

In contrast to the Early Devonian large beyrichiacean moulds, the silicified, mostly much smaller ostracodes from the western Pontides (Olempska et al., 2015) and those from SE Anatolia figured on a poster (Luppold et al., 2012) and the unpublished samples collected by Nazik from the Taurides show very nice lobation and ornament, but often the valve margins are less well preserved.

4. Taxonomic remarks

4.1. Introduction

The systematics of beyrichiacean ostracodes is based on details of lobation, ornamentation, and especially dimorphic features, especially of the heteromorphic (supposed female) valves. Crucial taxonomic features are in many cases only visible in well-preserved material like the calcareous carapaces from the Silurian of Gotland.

The dimorphic structures such as the crumina in heteromorphic specimens and the alate structure of some tecnomorphic (juvenile and male) specimens are known from external moulds of Early Devonian age, but they do not show the details of the ventral part of them like ridges or closing flaps as seen in calcareous material. Simple

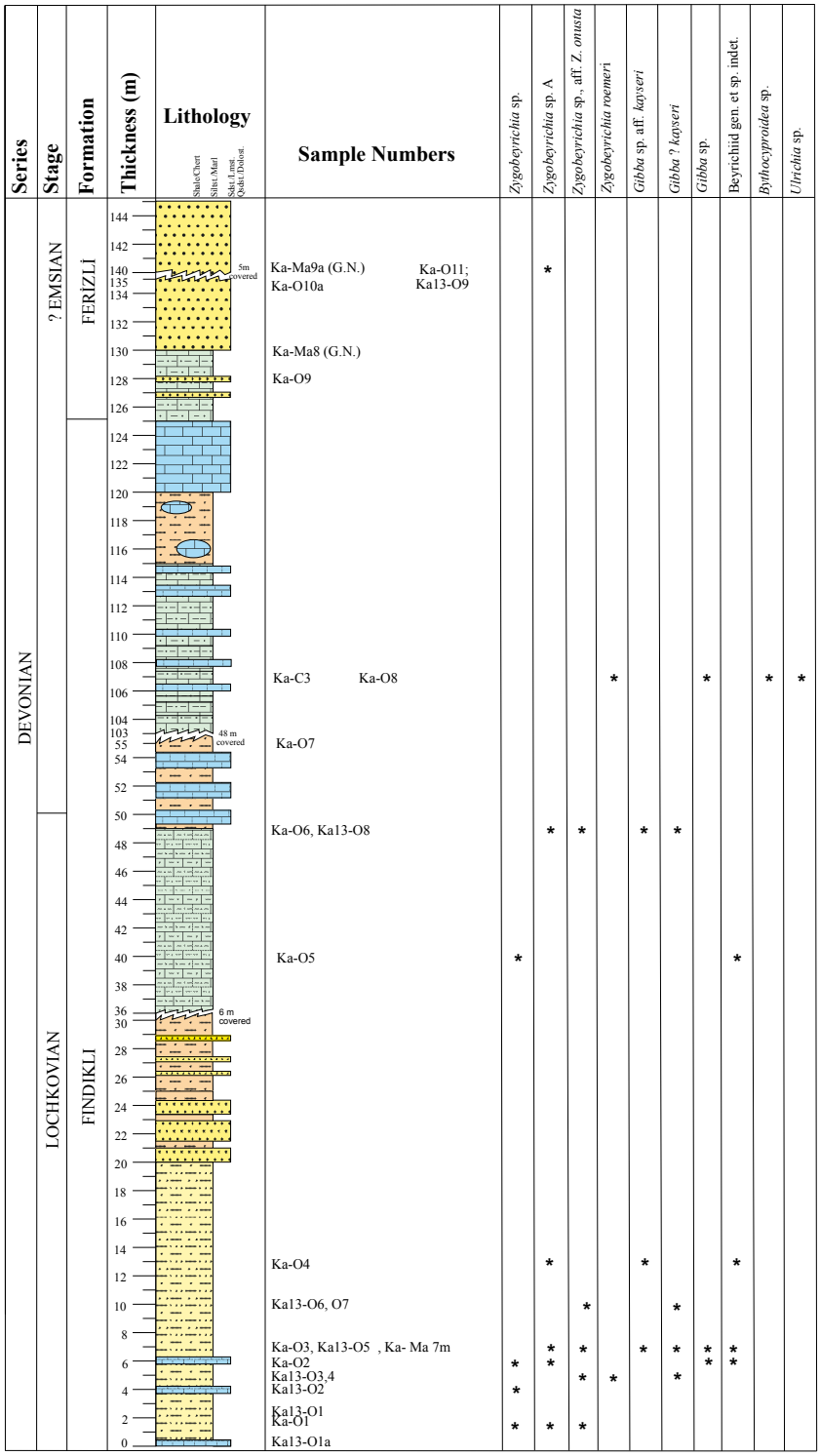


Figure 4. The distribution of ostracodes in the Kabalakdere section.

ridges of the ventral side of the crumina or alate structure are only sometimes preserved on external moulds (Figure 6).

The complicated adventral structures (marginal and velar structures) are much less preserved in Early Devonian beyrichiaceans from terrigenous sediments and only sometimes visible on external moulds.

The following terminology and abbreviations are used in the taxonomic descriptions and figures.

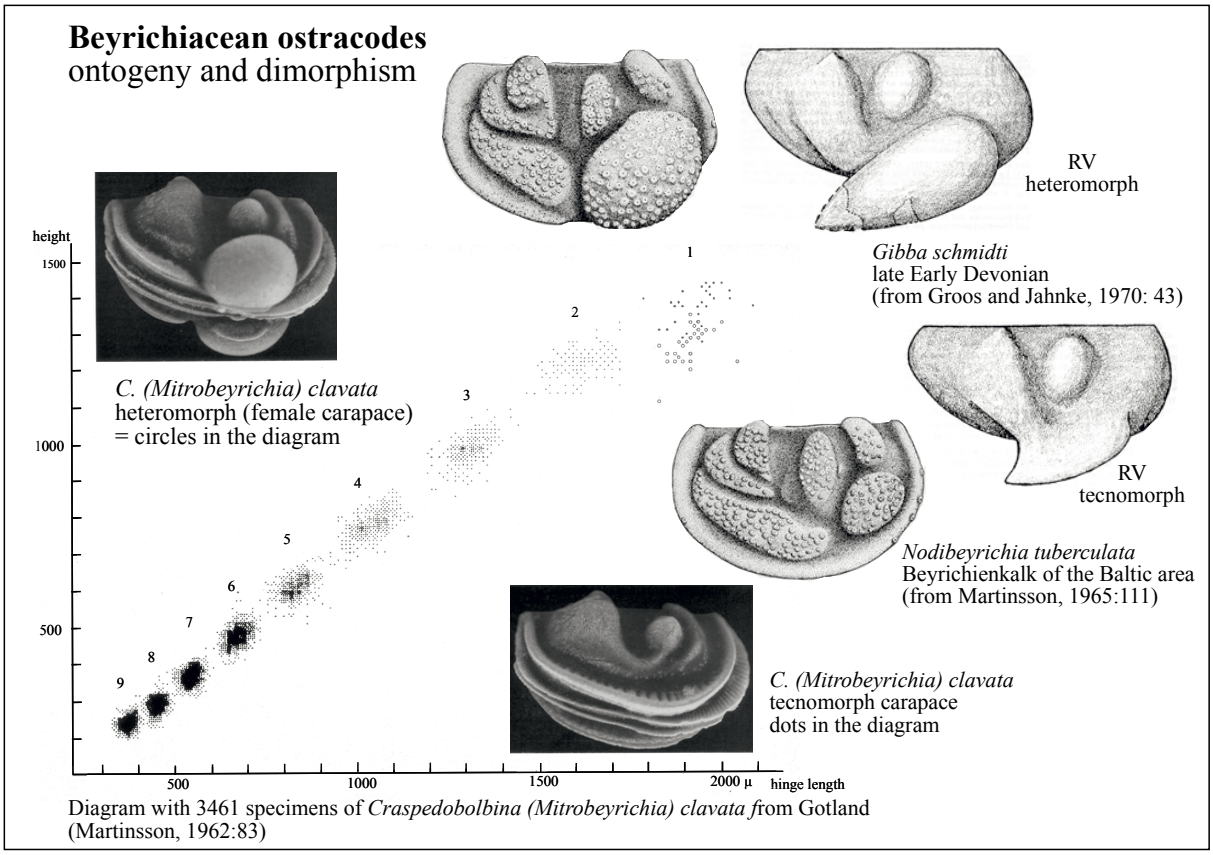


Figure 5. Beyrichiacean ostracodes: ontogeny and dimorphism of Silurian well-preserved *Craspedobolbina* (*Mitrobeyrichia*) *clavata* (Kolmodin, 1869) and *Nodibeyrichia tuberculata* (Klöden, 1834) in comparison with the internal moulds of the Early Devonian *Gibba schmidti* (Eichenberg, 1931). Right valves are figured.

Orientation: d = dorsal, v = ventral, lv = left valve, rv = right valve

Lobation: lobes L_1, L_2, L_3, ventral lobe = VL and sulci S_1, S_2

Ornamentation on the lobe: carina and tubercle

Lobule = small lobe

Measurements: length = L, height = H

Abbreviations for the collections:

DEVEC TR/E- = Collection of Atike Nazik deposited in the Geology Museum of İstanbul University, Avcılar Campus in Turkey

GBA = Collections of the Geological Survey of Austria in Vienna

GZG = Collections of the Geoscience Centre University of Göttingen

SMF Mbg. = Former collections of the Geological Institute of the University of Marburg, now deposited in the collections of the Senckenberg Museum Frankfurt

4.2. Beyrichiacean ostracodes

Superfamily Beyrichiacea Matthew 1886

According to the IRZN (4th edition of the International Rules of Zoological Nomenclature 2000: Glossary Superfamily name) the ending of the Palaeozoic ostracode superfamilies was changed from -acea to -oidea. Nevertheless, we prefer, like many colleagues working in the Palaeozoic (e.g., Perrier et al., 2011), to use the traditional and undisputed name Beyrichiacea instead of Beyrichioidea, following the discussions and decision during the ISO Meetings (International Symposia on Ostracoda), e.g., in Houston in 1982.

The systematic position of the large Early Devonian beyrichiacean ostracodes, such as those discussed here, is still debated because of the lack of important diagnostic features. Abushik (1971) defined the Carinokloedeniinae, her new subfamily within the Kloedeniidae Ulrich and Bassler, 1923, for those species with a sculptured L_2 and alate structure in tecnomorphs. This concept was followed by, e.g., Vannier (1994). The genus *Zygobeyrichia* was traditionally included in the Beyrichiidae (e.g., Moore, 1961) and was placed by Abushik (1971) into her new family Welleriellidae.

***Gibba* Fuchs, 1919**

non *Beyrichia spinosa* (Hall 1852) = *Aechmina spinosa* in Jones and Holl, 1869

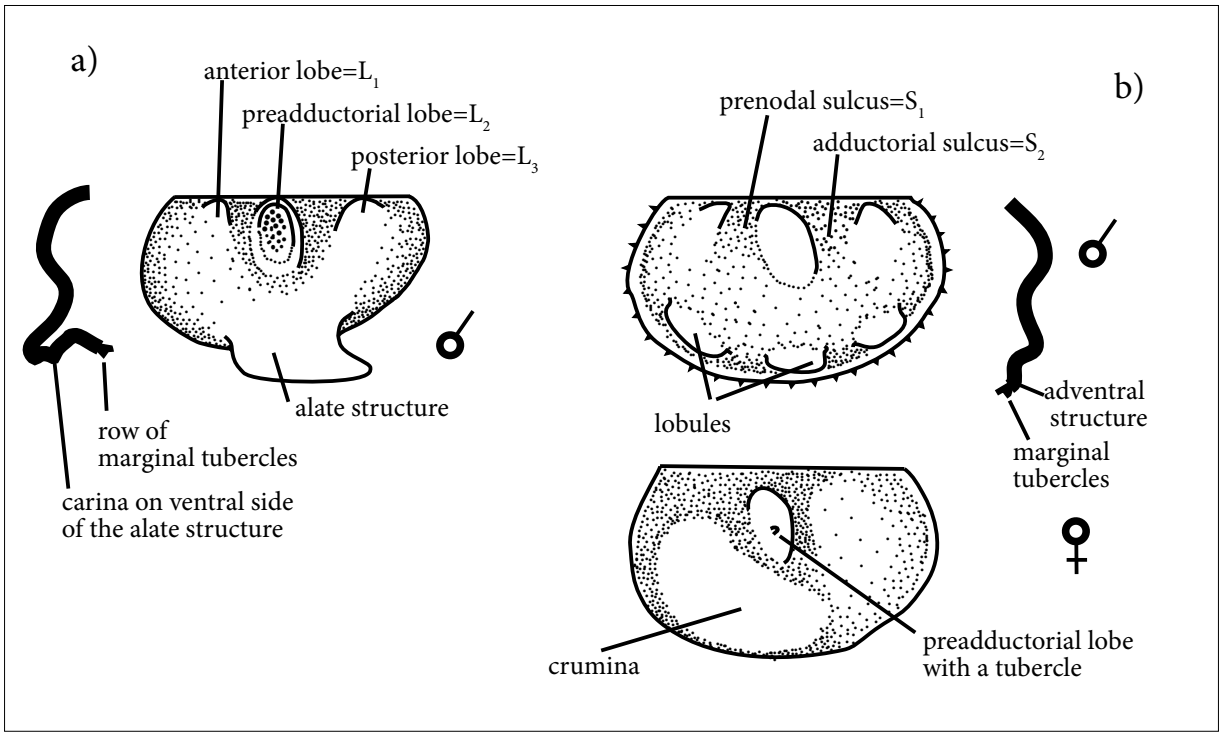


Figure 6. Terminology of Early Devonian beyrichiacean ostracodes**. a)** Tecnomorph left valve of *Gibba*, **b)** tecnomorph and heteromorph left valve of *Zygobeyrichia*.

= *Paraechmina spinosa* in Ulrich and Bassler, 1923

v 1919 *Beyrichia* (*Gibba*)- Fuchs: 81

1961 *Gibba* Fuchs, 1919- Howe: Q 413 (nomina dubia)

v 1971 *Carinokloedenia*- Abushik: 95–96

v 1986 *Carinokloedenia* Abushik, 1971- Groos-Uffenorde: 176

1987 *Carinokloedenia* (*Carinokloedenia*) Abushik, 1971- Pŕibyl: 358 (without *C. spinosa*)

1987 *Gibba* Fuchs, 1919- Schallreuter and Schäfer: 57, 58–59

1991 *Gibba*, Fuchs, 1919- Groos-Uffenorde: 342

1994 *Gibba* Fuchs, 1919- Vannier: 420

1996 *Gibba* Fuchs, 1919- Schallreuter: 53–54

2012 *Carinokloedenia* Abushik, 1971- Becker and Franke: 85–86

Type species: *Beyrichia* (*Gibba*) *spinosa* Fuchs, 1919

Characteristics: Large trilobate beyrichiacean ostracodes characterised by a rim around a prominent L_2. Tecnomorphs with a distinct alate structure (=wing-like lateral projection of Siveter, 1994) sticking out of the ventral part of the valve and with ribs on the lower surface of the crumina (respectively alate structure).

Subgenera (according to Schallreuter, 1996):

Gibba* (*Gibba*)** = ***Carinokloedenia sensu Abushik, 1971, e.g., in Becker and Franke (2012)

***Carinokloedenia* (*Carinokloedenia*)** in Pŕibyl, 1987

***Gibba* (*Gibbula*)** Schallreuter, 1996 = *Gibba* (*Schoeningibba*) in Schallreuter (1998)

***Gibba* (*Joachimokloedenia*)** Pŕibyl, 1987, with two ventral elongate nodes

Remarks: *Beyrichia* (*Gibba*) *spinosa* Fuchs, 1919 was thought to be an invalid junior homonym of *B. spinosa* (Hall, 1852) by Howe (1961), but was recognised as *Gibba spinosa* by Schallreuter and Schäfer (1987). According to these authors *Carinokloedenia* Abushik, 1971 is a junior synonym of *Gibba* Fuchs, 1919, assigned to Carinokloedeniinae Abushik, 1971, within Kloedeniidae and Beyrichiacea.

Gibba is similar to the monotypic *Ploteristes* Siveter, 1994 from the Early Silurian (Wenlockian of SW England), but in that genus, L_1 continues parallel to the anterior border in a bend that continues posteriorly until a small dorsal cusp (Siveter, 1994). This bend is less distinct in the Early Devonian beyrichiaceans and the dorsal cusp is missing. The alate structure of the tecnomorphs of *Carinokloedenia* Abushik, 1971 is much smaller and less distinct.

Stratigraphical distribution: Latest Silurian to latest Early Devonian.

Occurrences (see, e.g., Groos-Uffenorde, 1983; Vannier, 1994): Latest Silurian (Pridoli), Beyrichienkalk boulder of northern Germany. The occurrences in the Early Devonian of Germany (Rhenish Schiefergebirge, Harz and

Thuringia), northern France, Spain, Barrandium, Podolia, and Moldavia are summarised in, e.g., Groos-Uffenorde (1993). Additional occurrences are known from Morocco (e.g., Termier and Termier, 1950; Vannier, 1994) and Turkey (e.g., Paeckelmann and Sieverts, 1932).

***Gibba* ? *kayseri* (Kegel, 1913) (Figure 7: 1–3)**

v * 1913 *Kloedenia Kayseri* n.sp. - Kegel: 38–39, plate 2, figure 10

1918 *Kloedenia Kayseri* Kegel - Leidhold: 166, 167

1934 *Kloedenia Kayseri* Kegel - Bassler and Kellet: 363

1954 *Kloedenia Kayseri* Kegel - Roesler: 117, 118

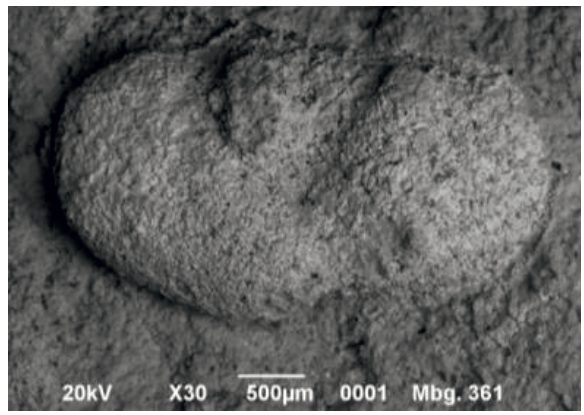
v 1964 *Zygobeyrichia kayseri* (Kegel) - Jordan: 33, plate 6, figure 18, plate 25, figure 6

v 1970 *Zygobeyrichia kayseri* (Kegel, 1913) - Groos and Jahnke: 44

v 1982 *Zygobeyrichia kayseri* (Kegel, 1913) - Groos-Uffenorde: 215

Lectotype designated herein: Internal mould of a heteromorph left valve (SMF Mbg. 361), with L = 3.65 mm and H = 2.05 mm. Now deposited in the Senckenberg Museum Frankfurt) and labelled 'Nauheim, Alte Limburger Straße, Kegel 1911'; published locality 'Volkersberg'.

1a



1b

2a

2b

2c

3a

3b

4

Figure 7. 1–3) *Gibba* ? *kayseri* (Kegel, 1913). **1)** Internal mould of heteromorph left valve, lateral view of the lectotype, (SMF Mbg. 361), L = 3.65 mm and H = 2.05 mm; **a)** photo Uffenorde (GR-UFF 306a.jpg); and **b)** JEOL-photo SMF Mbg. 361 1-b. **2)** Internal mould of heteromorph left valve on SMF Mbg. 363, from 'Niederneisen, Volkersberg 1912', L = 3.3 mm and H = 2.2 mm; **a)** lateral view, **b)** oblique dorsal view, **c)** ventral view. **3)** Specimens from the Kabalakdere section; **a)** internal mould of right valve (DEVEC TR/E-16), **b)** internal mould of left valve (DEVEC TR/E-17). **4)** *Gibba* ? sp., aff. *kayseri*, internal mould of tecnomorph left valve, Kabalakdere section (DEVEC TR/E-18).

A diagnostically important feature is the small posteroventral lobule below a short L_3. The suboval knoblike L_2 is surrounded by a short S_1 and long S_2. The relatively large crumina is dorsally fused with the indistinct L_1 and extends from the anterodorsal to behind midventral and ventrally somewhat projects out of the valve.

Further material from the Early Devonian of the type area in the Rhenish Schiefergebirge of Germany: A second heteromorph internal mould was cited by Groos-Uffenorde (1982) from the slab SMF Mbg. 363 with '*Beyrichia roemeri* Kays' figured by Kegel (1913) (= *Zygobeyrichia devonica* Jones and Woodward, 1889). These two slabs (part and counterpart of SMF Mbg. 363) labelled by Kegel '*Kloedenia kayseri* Kgl, *Beyrichia roemeri* Kays' show an additional internal mould of a heteromorph left valve of *Z. kayseri* from 'Niederneisen, Volkersberg 1912' together with incomplete tecnomorphic internal moulds.

One external mould of a heteromorph right valve of *Z. kayseri* with the lobule below L_3 was observed by Helga Uffenorde in 1969 in the collection of the Palaeontology Museum of Berlin labelled '*Kloedenia kayseri* Kegel, tug Volkersberg, Bl. Limburg, leg Kegel 1920', but no ornamentation could be found on L_2.

Remarks: Despite the fact that Kegel (1913) did not choose a holotype, Jordan (1964: 33) took the figured specimen of Kegel (1913: plate 2, figure 10) as a holotype. We take this specimen as a lectotype. Kegel (1913) used a reversed orientation and cited two fine anterior 'warts' ('nahe der Vorderfuche zwei feine warzenförmige Erhebungen') occurring only in heteromorphic specimens.

Recently, tecnomorphic internal moulds of *G.*? *kayseri* have been found in the Turkish Kabalakdere section. They are characterised by the posteroventral distinct small node in addition with a short alate structure. Hitherto only internal moulds have been found and ornamentation such as carinated lobes or carinae on the ventral side of the alate structure or crumina could not be verified.

The species is placed in the genus *Gibba* because an alate structure is unknown in the genus *Zygobeyrichia*. A pronounced anteroventral crumina ventrally projecting out from the valve, like those of Kegel's specimens, is also characteristic for *Gibba*.

Remarks: The tecnomorphs of "*Zygobeyrichia*" sp. B, aff. *Z. kayseri* (Kegel, 1913) sensu Groos-Uffenorde (1982) are characterised by an additional ventral lobule below L_2 and therefore are closely related to *Carinokloedenia jargarensis* Abushik and Trandafilova (1977). The latter shows a bulbous L_2 and two pronounced ventral lobules in tecnomorphs, and with a less isolated crumina of the heteromorphs.

Occurrence: The materials of Kegel came from the Rhenish Schiefergebirge/Germany: Taunusquarzit, middle to late Siegenian. The new Turkish specimens are from the Kabalakdere section/NW Turkey: Findikli Formation (sample number Ka13-O4, Ka13-O5, Ka13-O8), Lochkovian according to brachiopod data.

***Gibba* ? sp., aff. *Kayseri* (Figure 7: 4)**

Remarks: Some specimens show a reversed ornamentation; that is, L_1 is divided into two tubercles instead of the subdivided L_3.

Material: Kabalakdere section, samples Ka-O3, Ka-O4, Ka13-O-8.

Occurrence: Findikli Formation, earliest Early Devonian, Lochkovian in NW Turkey.

***Zygobeyrichia* ? sp. B, aff. *Z. kayseri* sensu Groos-Uffenorde (1982)**

1982 "*Zygobeyrichia*" sp. B, aff. *Z. kayseri* (Kegel, 1913) - Groos-Uffenorde: 216, plate 2, figures 10–13

1983 *Zygobeyrichia* sp. B, aff. *Z. kayseri* - Groos-Uffenorde: 348, 349

Remarks: The species is characterised by a differentiation of the ventral lobe into 3 elongate lobules below the short L_1 and L_3 and the oval L_2. Heteromorphs with inflated anterior lobe (combined L_1 and anterior lobule) but much less inflated and isolated as within *G.*? *kayseri* and therefore a provisional position within *Zygobeyrichia* is still preferred.

Occurrence: Hitherto known only from late Siegenian sediments of northern France and Rhenish Schiefergebirge (Germany).

***Gibba* sp., aff. *G.* spinosa sensu Paeckelmann and Sieverts, 1932**

1932 *Beyrichia* sp. aff. *spinosa* Fuchs - Paeckelmann and Sieverts: 9, plate 2, figure 4

1964 *Zygobeyrichia* sp., aff. *spinosa* (Fuchs) - Jordan: 31, plate 2, figure 12

1986 *Carinokloedenia spinosa* (Fuchs, 1919) - Groos-Uffenorde: 176–178, plate 29, figures 1–5

2012 *Carinokloedenia spinosa* (A. Fuchs, 1919) - Becker and Franke: 87

Remarks: Groos-Uffenorde (1986) assigned the subspecies of Abushik and Trandafilova (1977) from the Early Devonian of Moravia to *Carinokloedenia spinosa* (now *Gibba spinosa*) and proposed *G. spinosa spinosa*, *G. spinosa alata*, *G. spinosa laevis*, and *G. spinosa retiformis*.

Becker and Franke (2012) introduced *Carinokloedenia spinosa* sp. A forma *reideschbaachensis* n. from the Early Emsian ('Ulmen-Unterstufe') of Luxemburg with relations to *C. schmidti*.

Two incomplete tecnomorph internal moulds of right valves were collected by Paeckelmann (1925) from the Early Devonian (Emsian 'Pendik Schichten') of NW Turkey. They show similarities to *Gibba spinosa* as well as to *Gibba schmidti*.

It seems likely that the Turkish Early Devonian moulds of *Gibba* sp., aff. *G. spinosa* sensu Paeckelmann and Sieverts 1932 may belong to *Gibba schmidti* (Eichenberg, 1931).

Stratigraphical distribution: Early Devonian.

Occurrence of C. spinosa: Early Devonian (Gedinnian) of Germany, Belgium, northern France. Doubtful occurrences in the Early Emsian of Luxemburg (Becker and Franke, 2012) and badly preserved specimens figured from the Early Devonian of Morocco/North Africa (Termier and Termier, 1950).

***Gibba schmidti* (Eichenberg, 1931) (Figures 8 and 9)**

1897 *Beyrichia* sp. - Denckmann, 158

1923 *Beyrichia tetrapleura* Fuchs - Bode: 204

v * 1931 *Beyrichia schmidti* n.sp. - Eichenberg: 172–174, plate 8 figure 8, figure 5: 2, 10, 12, 13

1931 *Beyrichia bodei* n.sp. - Eichenberg: 174, plate 8, figure 9, text-figure 5, figures 1, 4, 9, 18

v 1970 *Zygobeyrichia* ? *schmidti* (Eichenberg) - Groos and Jahnke: 41–45, plate 1, figures 5–12 (see synonymy)

1971 *Carinokloedenia schmidti* (Eichenberg, 1931) and *C. bodei* (Eichenberg) - Abushik: 95, 97–98

1974 *Carinokloedenia schmidti* - Becker and Bless: 4, text-figure 1, text-figure 4

v 1979 *Carinokloedenia schmidti* (Eichenberg, 1931) - Gooday and Becker: 195, figure 2

v 1982 *C. schmidti* - Groos-Uffenorde: 210

1982 *Carinokloedenia schmidti* (Eichenberg, 1931) - Becker and Groos-Uffenorde: 303, plate 1, figures 4–5

v 1983 *C. schmidti* - Groos-Uffenorde: 348, 349

v 1987 *Carikloedenia* (*Carikloedenia*) *schmidti* (Eichenberg, 1931) - Přibyl: 360-361, text-figure 1, figure 9, plate 1, figures 1–4

? v 1991 *Gibba schmidti* (Eichenberg, 1931) - Groos-Uffenorde: 342, plate 1, figures 1–3

2006 *Carinokloedenia* cf. *schmidti* (Eichenberg 1931) - Basse and Franke: 11

p v 2012 *Carinokloedenia schmidti* (Eichenberg 1931) - Becker and Franke: 89

?? 2012 *Carinokloedenia spinosa* sp. A *forma reideschbaachensis* n.form - Becker and Franke: 87–88

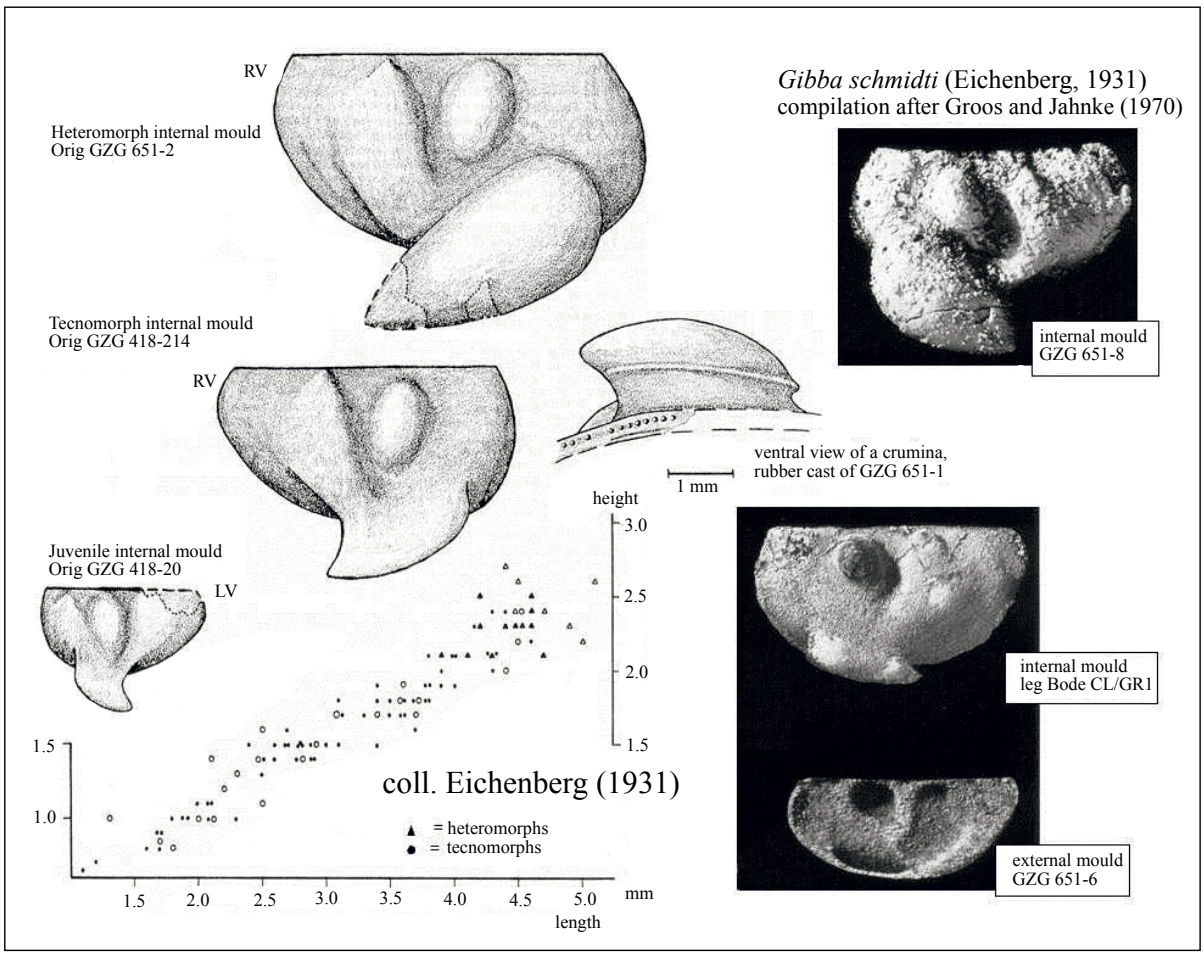


Figure 8. *Gibba schmidti* (Eichenberg, 1931) from the Early Devonian of Germany, combination of text-figures and photos from Groos and Jahnke (1970), ontogeny and dimorphism.

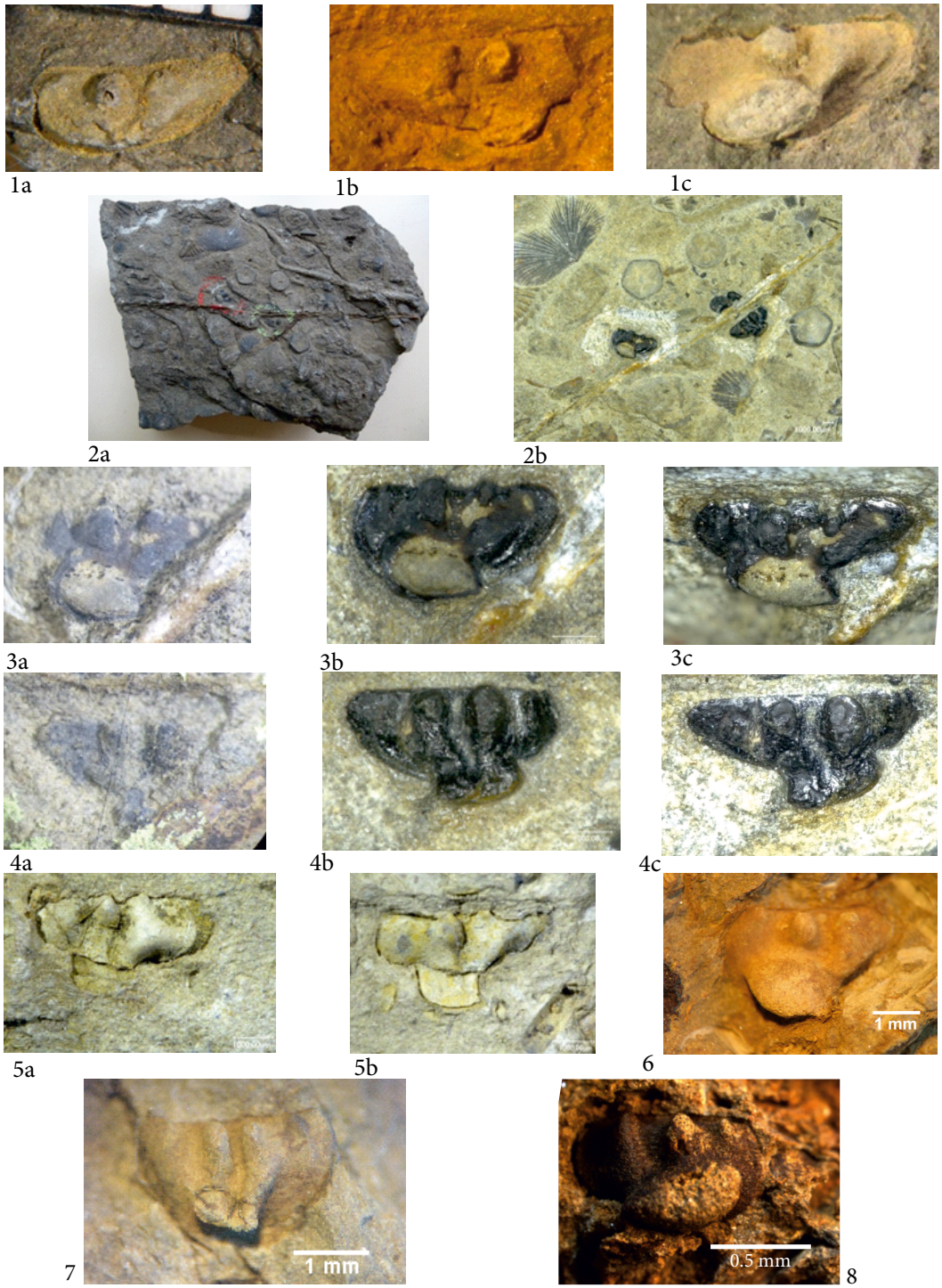


Figure 9. *Gibba schmidti* (Eichenberg, 1931) from Early Devonian of Turkey. **1)** Material of Kayser (1899) (collection of Toula in Vienna) from Kanlıca; **a)** Inv. Nr.: GBA 1900/002/0012 (photo I. Zorn 20/05/2014), internal mould of a tecnomorph left valve, alate structure broken, **b)** internal mould of a tecnomorph right valve (Inv. Nr.: GBA 1900/002/005, photo A. Nazik 23/07/2014), **c)** internal mould of a heteromorph left valve (Inv. Nr.: GBA 1900/2/4, photo A. Nazik 23/07/2014). **2–4)** Collection of Endriss deposited in Frankfurt, label "Tuzla/Bosphorus Dr. Endriss 1908"; **a)** specimen before and **b–c)** after the preparation by Olaf Vogel and photos by M. Ricker (both SMF). **2a–b)** Fossiliferous marly crinoidal limestone SMF Mbg. 7232 showing specimens of **3** and **4**. **3a–c)** Slightly corroded heteromorph left valve, lateral and dorsal view; SMF Mbg. 7232/1, L = 4.8 mm. **4a–c)** Internal mould of tecnomorph right valve, lateral and dorsal views, SMF Mbg. 7232/2, L = 4.3 mm. **5)** Two tecnomorph internal moulds of left valves from a very fossiliferous siltstone slab in the SMF collection (labelled '*Beyrichia roemeri* Kayser' Yakadjik, coll. Endriss 1908); **a)** SMF 7233/1, L = about 4.6 mm and **b)** SMF Mbg. 7233/2, L = more than 4.5 mm. **6)** Internal mould of heteromorph left valve coll. Nazik, Darlik section (DEVEC TR/E-19. **7)** Internal mould of tecnomorph left valve, coll. Nazik, Darlik section, DEVEC TR/E-20. **8)** Internal mould of heteromorph (?) right valve, coll. Nazik, Kabalakdere section, DEVEC TR/E-21.

Lectotype: Designated by Groos and Jahnke (1970) (internal mould, GZG Göttingen Orig.-Nr. 418-11, coll. Eichenberg 1928), Early Emsian 'Rothäuser Grauwacke', Harz Mountains/Germany.

Diagnostically important features are the lobate valves with prominent carinated L_2 and long adductorial sulcus (S_2) besides a broad alate structure near the ventral border. A straight narrow rib is developed on the ventral side of the alate structure of tecnomorphs and on the crumina of heteromorphs (see Figure 8). A carina runs parallel to the posterior border. A narrow carina surrounds the prominent preadductorial lobe (L_2) and is only visible in external moulds (e.g., as seen in latex casts) and is mostly not seen on internal moulds. The ontogeny and dimorphism of *Gibba schmidti* (Eichenberg, 1931) from Germany is shown in Figure 8.

Remarks: According to Groos and Jahnke (1970) *Beyrichia schmidti* is the tecnomorph and *Beyrichia bodei* the heteromorph of *Gibba schmidti* (the two types were mixed up in Abushik, 1971).

A narrow carina surrounds the prominent preadductorial lobe (L_2) and is only visible in external moulds (e.g., as seen in latex casts) and is mostly not seen on internal moulds. The large alate structure shows a straight narrow rib on its ventral side.

The relationship to the similar *Gibba latispinosa* Přibyl, 1952 has still to be verified.

Gibba schmidti sensu Groos-Uffenorde (1991) is questionably included in *Gibba kandarensis* Vannier, 1994.

Stratigraphical distribution: Early Devonian.

Occurrences: Early Devonian (late Siegenian to Emsian) of Germany, southern Spain; Emsian of Bohemia, northern France. In Turkey: *Beyrichia* sp. aff. *spinosa* sensu Paeckelmann and Sieverts 1932 from 'Pendik Schichten', Early Devonian. *Gibba schmidti* from Kanlıca (coll. Toula), Tuzla and Yakacık (coll. Endriss), Early Devonian. All recently found specimens from the Darlik section (coll. Nazik) are of Emsian age.

***Zygobeyrichia* Ulrich, 1916**

* 1916 *Zygobeyrichia* n.gen. - Ulrich: 290–291

1934 *Zygobeyrichia* Ulrich - Bassler and Kellett: 494

1958 *Zygobeyrichia* - Pokorny: 165

1961 *Zygobeyrichia* – Berdan: Q 122

1962 *Zygobeyrichia* Ulrich 1916 - Martinsson: 266

1968 *Zygobeyrichia* - Zagora: 13–15

v 1970 *Zygobeyrichia* Ulrich 1916 - Groos and Jahnke: 41

v 1983 "*Zygobeyrichia*" - Groos-Uffenorde: 338

1996 *Zygobeyrichia* Ulrich 1916 - Becker: 140–141

2005 "*Zygobeyrichia*" Ulrich 1916 - Dojen: 56

2012 *Zygobeyrichia* Ulrich 1916 - Becker and Franke: 92

Type species: *Zygobeyrichia apicalis* Ulrich, 1916

Characteristics: Large trilobate beyrichiacean ostracodes (late Silurian to Devonian), which according to Ulrich (1916) are characterised by a varying distinctness of the ventral connection between L_1 and L_2 (zygal ridge).

The genus is mostly assigned to the Beyrichiinae resp. Beyrichiidae.

Remarks: A closely related genus is *Arikloedenia* Adamczak, 1968, which does not show a distinct adventral structure in adults. According to Přibyl (1986), *Arikloedenia zlichovensis* (Přibyl, 1955) seems to be related to '*Zygobeyrichia* (recte *Arikloedenia*) *subcylindrica* (R.Richter)'.

According to Berdan (1972), the crumina of *Lophoklodenia* and *Zygobeyrichia* interrupts the velar ridge in contrast to *Kloedeniopsis* Berdan, 1972.

According to Groos and Jahnke (1970), there are close relationships between *Z. apicalis* and *Z. devonica*, i.e. between North American and European species.

Occurrences: Late Silurian and Early Devonian of North America, Early Devonian of Germany (Rhenish Schiefergebirge, Harz, Thuringia), northern France, Spain, Bohemia, Turkey.

The oldest but very doubtful record of *Zygobeyrichia* is *Zygobeyrichia*? sp. A sensu Wolfahrt (1970) from Middle Ordovician sediments near Malestan in eastern Afghanistan (Wolfahrt, 1970).

The youngest supposed record of the genus is a very small specimen of *Zygobeyrichia*? *carinata* (Kummerow, 1953) sensu Becker (1965), from the early Middle Devonian of the Eifel area/Germany, but it is not yet restudied or revised.

***Zygobeyrichia roemeri* (Kayser, 1899) (Figure 10)**

non 1863 *Beyrichia* spec. - Roemer: 521–522, plate V, figure 9a, b = *Z. devonica*)

* 1899 *Beyrichia Roemeri* n.sp. - Kayser: 30, 35, plate 1, figure 9 = external moulds, plate 1, figure 10 = calcareous valve

1912 *Beyrichia Roemeri* Kayser - Leidhold: 719, 720, 721, 722

non 1913 *Beyrichia Roemeri* Kayser - Kegel: 40–41, plate 2, figure 12 = *Z. devonica* Jones

1918 *Beyrichia Roemeri* Kayser - Leidhold: 167

1918 *Beyrichia Roemeri* Kayser - Hüffner: 273

1918 *Beyrichia Roemeri* Kayser - Leidhold: 310–311, plate 13, figure 7

1919 B*eyrichia Roemeri* Kayser - Vietor: 363

1925 *Beyrichia Roemeri* Kayser - Paeckelmann: 105

v 1932 *Beyrichia roemeri* Kayser - Paeckelmann and Sieverts: 9, plate 2, figure 20

1934 *Beyrichia* (*Zygobolba*?) *roemeri* Kayser - Bassler and Kellett: 205

1935 *Beyrichia roemeri* Kayser - Dahmer: 139

?? 1935 *Beyrichia Roemeri* Kayser - Péneau: 45–47, figure 2

1938 B*eyrichia roemeri* Kayser - Paeckelmann: 26, 27, 55, 61, 65, 66, 72, 85, list p. 90, 104, 105, 107, 108, 111, 113

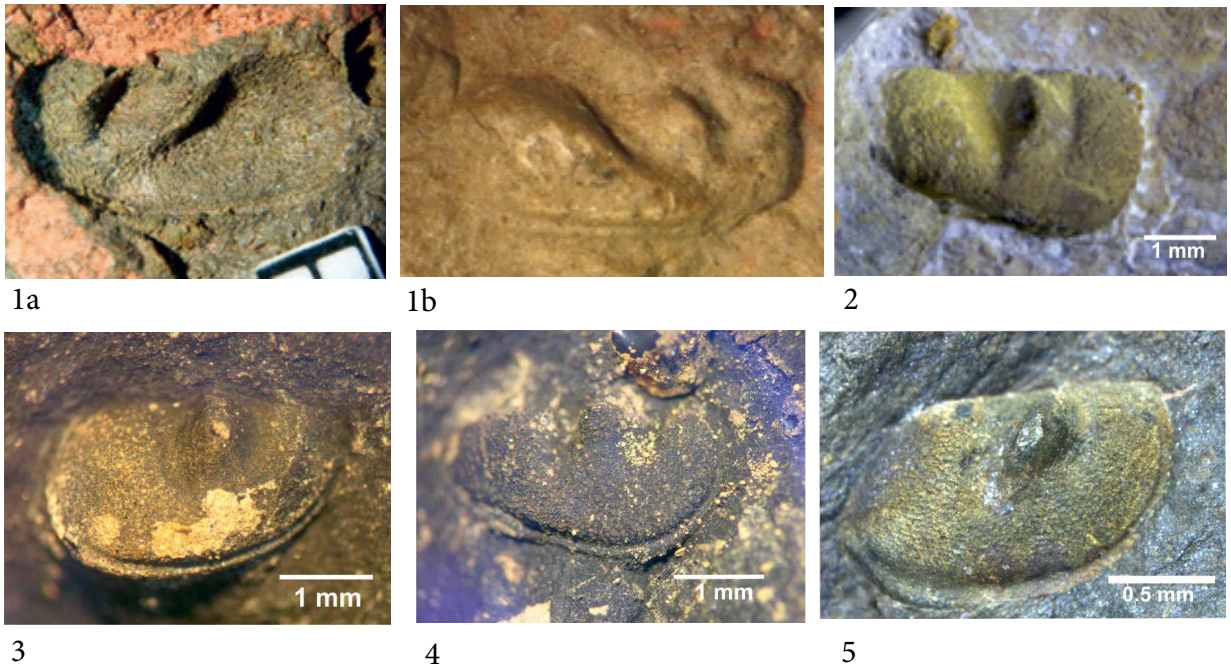


Figure 10. *Zygobeyrichia roemeri* (Kayser, 1899). **1)** Lectotype, squashed tecnomorph right valve, locality Kanlydsha/Kanlıca, Turkey (Inv. No.: GBA 1900/002/0005); **a)** external mould (photo by I. Zorn 20/05/2014), **b)** original cast figured by Kayser (1899: plate 1, figure 9) (photo by A. Nazik 23/07/2014). **2)** External mould of a heteromorph (?) left valve, SMF Mbg. 7234/1 (label '*Beyrichia roemeri* Kayser' from Yakadjik, coll Endriss 1908). **3)** Latex cast of external mould of a tecnomorph, coll. Nazik, Darlik section, DEVEC TR/E-22. **4)** Latex cast of external mould of a tecnomorph, coll. Nazik, Darlik section, DEVEC TR/E-23. **5)** External mould of juvenile specimen of a tecnomorph, coll. Nazik, Kabalakdere section, sample DEVEC TR/E-24.

1946 *Beyrichia roemeri* Kayser - Asselberghs: 249

v 1964 *Beyrichia* ? *roemeri* Kayser - Jordan: 36, plate 25, figure 7 and plate 27, figure 31

non 1964 *Beyrichia* ? *roemeri* Kayser - Jordan: 36, plate 6, figure 30 = rough drawing of Kegel's type

non 1964 *Beyrichia* ? *roemeri* Kayser - Jordan: 36, plate 25, figure 8 = photo of Kegel's specimen

non 1982 *Zygobeyrichia roemeri* (Kayser, 1899) sensu Kegel (1913) - Groos-Uffenorde: 218 = *Z. devonica* Jones

pv 2010 *Beyrichia roemeri* Kayser, 1900 - Zorn 2010: 268, plate 3, figures 39–40 (reproduction of figures from Kayser 1899)

Lectotype designated herein: The squeezed external mould of '*Beyrichia Roemeri*' Kayser 1899 on a slab, GBA Vienna, Inv. No: GBA 1900/002/0005, locality Kanlydsha, Early Devonian greywacke (Syntypus in Zorn, 2010). This external mould together with a latex cast is figured (Figure 10: 1a, 1b).

The type material of *Beyrichia roemeri* Kayser, 1899 from the Bosphorus area (collection of F. Toula, 1895) has recently been found in the collections of the Geological Survey in Vienna by Zorn (2010): the figured calcareous valve (Kayser 1899, plate 1, figure 10) from the calcareous layer (GBA 1900/002/0028, locality between Pendik and Kartal) and slightly squeezed external moulds ('Hohlraum' sensu Kayser) together with artificial casts ('Abdrücke' = Abgüsse) of external moulds from Kanlydsha (GBA 1900/002/0005).

In addition, Kayser (1899, p. 30) reported several external and internal moulds, with varying shape with L = 5–6 mm and H = 3 mm (he cited 'bis 3 mm lang und 5–6 mm breit'), but this material could not be found.

Diagnostically important features: Relatively large *Zygobeyrichia* with straight dorsal border, subamplete outline and distinct, elongate L_2. The distinctness and size of the L_1 and L_3 varies and they may be weakly connected ventrally with the L_2. The L_1 and L_3 are less pronounced in juveniles. The surface of the valve is finely reticulated to distinctly granulated. A tubercle on the L_2 is neither reported nor seen in the new material.

Remarks: *Zygobeyrichia favaria* (Kummerow, 1953) seems to be similar in lobation and reticulation, but the adult specimens are much smaller and the reticulation of *Z. roemeri* is not as coarse as within the Early Devonian *Z. favaria* (Kummerow, 1953).

The related species *Zygobeyrichia subcylindrica* is characterised by a tubercle on L_2 and does not show the reticulation of *Z. roemeri*. The rare and poorly preserved *Zygobeyrichia* ? sp. 2 sensu LeFèvre (1963) from the Emsian of the Algerian Sahara may be related to *Z. roemeri*.

Material: The original description is based on moulds, but only two artificial casts of distorted moulds were figured by Kayser. The better preserved, figured calcareous valve does not belong to *Z. roemeri* because this specimen differs from the drawing of figure 10 in Kayser (1899, plate 1, figure 10), in which the outline is more elongate, the anterodorsal corner is missing, and the shell is damaged on L_1 and L_2. A photo (courtesy of I. Zorn) of this calcareous valve is shown subsequently in this text as *Zygobeyrichia subcylindrica* vel *Zygobeyrichia devonica.*

As early as Kegel (1913) it was doubted that the figured Turkish specimens of Kayser were conspecific. Kegel's specimen from the Early Devonian of Germany (this internal mould, GPI MR 363, was deposited in the former collection of the GPI Marburg, refigured by Jordan 1964, and is now deposited in the collection of the Senckenberg Museum Frankfurt) is less elongate compared with the calcareous specimen of Kayser (1899) and all three narrow lobes are connected ventrally; it may belong to *Zygobeyrichia devonica* (Jones and Woodward, 1889) (see *Z. subcylindrica*).

Hüffner (1918) published on the collections of Turkish fossils of Endriss and cited *Beyrichia roemeri* Kayser from Yakacık. An external mould of the Endriss collection (SMF Mbg. 7234/1) from Yakacık is shown in Figure 10 (2).

Paeckelmann and Sieverts (1932) figured *Beyrichia roemeri* Kayser (leg. Paeckelmann 17.05.1927 from the Pendik Fm. of Bakkalköy), which was refigured by Jordan (1964, pl. 25, fig. 7 and pl. 27, fig. 31) as *Beyrichia* ? *roemeri* Kayser. The external mould shows a distinct granulated surface (Jordan, 1964).

Paeckelmann published (1938) many occurrences of *Beyrichia roemeri* from different localities in the "Pendik Schichten", including the collections of Endriss.

Péneau (1935) compared specimens of *Beyrichia roemeri* from the Calcaire de Vern, France, with the figured specimen of Leidhold (1918) collected in Turkey, but the figured French specimen (L = 2 mm and H = 1.25 mm) is much smaller than that from Turkey. Leidhold's (1918) specimen measured up to 7 mm in length and 4 mm in height with varying outline; these measurements are slightly bigger than but comparable to those cited by Kayser (1899).

New Turkish material has been collected from the Emsian Kartal Formation of the Darlik section (sample numbers D-O-1a, 1, 1c, 2, 2a, 2b, 3) and the Korucuköy section (sample numbers KOB-2a, 3, 4, 5, 5b, 5c).

Occurrence: Late Early Devonian (Emsian) of Europe and Turkey.

***Zygobeyrichia favaria* (Kummerow, 1953) (Figure 11)**

v ? 1932 *Beyrichia roemeri* Kayser - Paeckelmann and Sieverts: 9, plate II, figure 20

v * 1953 *Beyrichia favaria* n.sp. - Kummerow: 36, plate 3, figure 12

v 1964 *Beyrichia* (*Neobeyrichia*) *favaria* Kummerow, 1953 - Jordan: 29, plate 25, figures 1–2, plate 27, figure 28

v ? 1964 *Beyrichia* ? *roemeri* Kayser. - Jordan: 36, plate 27, figure 31

non 1996 *Zygobeyrichia favaria* (Kummerow, 1953) - Becker: 141, figure 7:2

The diagnostically important features are the relatively small size, the reticulated surface, the distinct adventral structure, and an indistinct anteroventral crumina.

Remarks: The type material (studied by H Groos-Uffenorde, 1969, in the ZGI Berlin) is not very well preserved and partly distorted: the internal mould of the holotype (ZGI X 466) is slightly incomplete (L = 2.2 and H = 1.5 mm, see Jordan, 1964, pl. 25, figure 1) and the external mould does not exist.

Measurements of internal moulds: Heteromorph with L >2.3 and H = ca. 1.5 mm and tecnomorph with L = 2.2 and H = 1.5 mm (ZGI t 406), and a heteromorph with swollen L_1 (crumina not well isolated) with L >2.4 and H = 1.8 mm (ZGI t 410/2).

Jordan (1964) refigured the types of Kummerow (1953), but only internal moulds with pronounced lobation. Hitherto, no additional material has been described from Kummerow's Early Devonian localities in the Eifel area of Germany.

The lobes of the types of the larger *Zygobeyrichia roemeri* (Kayser, 1899) from the Turkish Early Devonian seem to be more elevated, but the lobation of the specimen figured in Paeckelmann and Sieverts (1932) and refigured by Jordan (1964) is very similar to *Z. favaria.*

The lobation and distinct admarginal rim of *Z. favaria* resembles *Zygobeyrichia subcylindrica*, but the adults of the latter are much larger and characterised by a granulated surface and often a distinct tubercle on L_2.

The surface of "*Zygobeyrichia*" n.sp. 2, aff. *Z. favaria* (Kummerow, 1953) sensu Groos-Uffenorde (1983) is as well reticulated, and in contrast it has a tubercle on the oval and pointed L_2. The L_1 and L_3 are ventrally only weakly connected. The difference from *Z. favaria* is the much more pronounced ventral part of L_1 and L_3 and a finer reticulation. Often 1 or 2 rows of admarginal tubercles are also preserved.

Well-preserved external and internal moulds have been collected by K.-H. Ribbert (Krefeld) from near Kummerow's type locality in the Eifel area of Germany. Specimens from Germany and Spain are shown in Figure 11 for comparison with specimens of *Zygobeyrichia roemeri* from Turkey.

Occurrences: Early Devonian (? Siegenian - Emsian) of Europe.

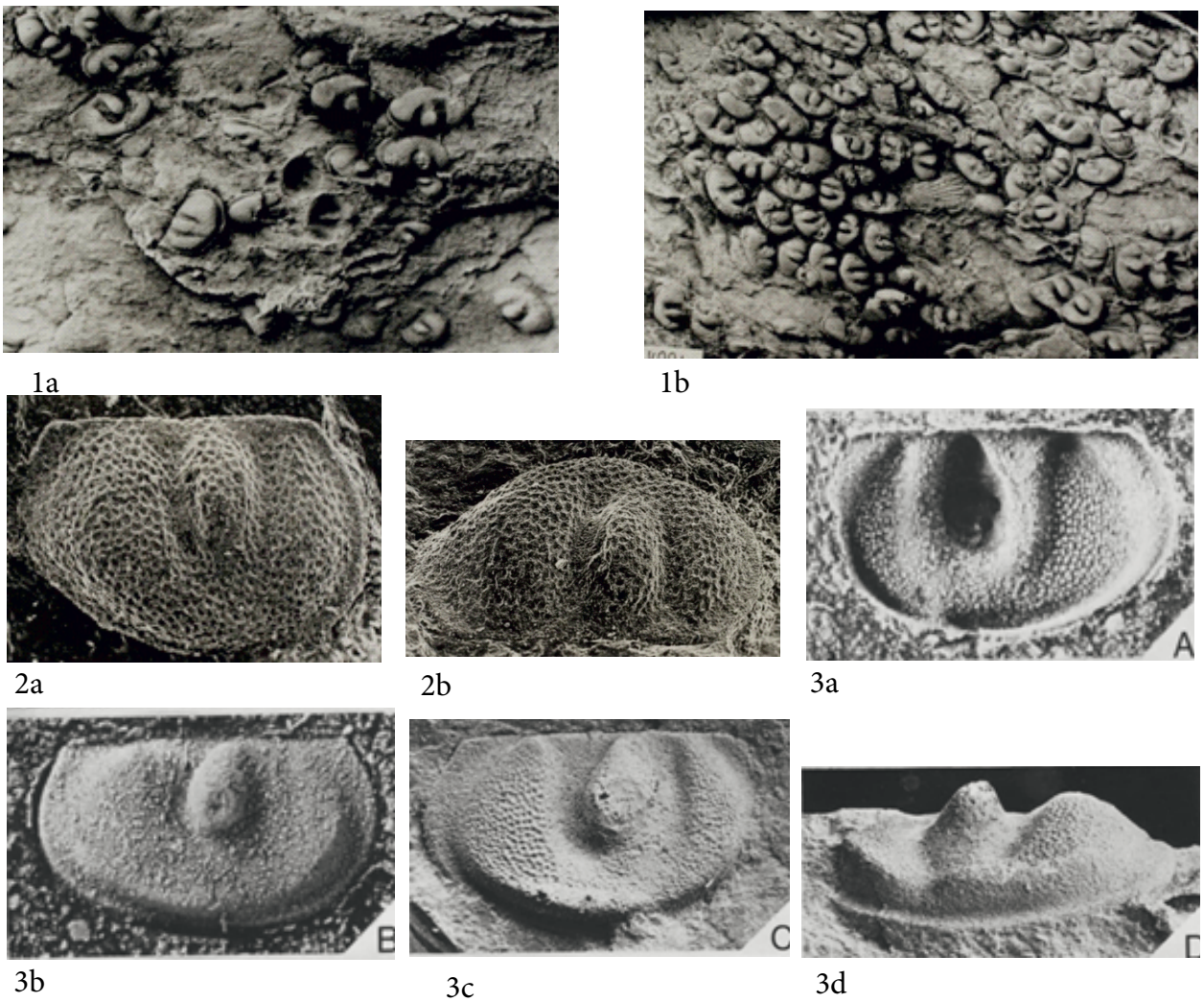


Figure 11. 1–2) *Zygobeyrichia favaria* (Kummerow, 1953), leg. K.-H. Ribbert (Geol Survey NRW, Krefeld), black shale with mass occurrence of single valves of juveniles and adults, tectonically slightly squeezed, Hellenthal, sample GR 1499, Orig.-Nr. GZG GÖ 1615, Early Devonian, Eifel area, Germany. **1)** Latex cast of a bedding plane, Orig.-Nr. GZG GÖ 1615-1499-4; **a)** Aristophot-Film GR 4/1991:9, **b)** Aristophot-Film GR 4/1991:6. **2)** Latex cast of a right external mould, Orig.-Nr. GZG GÖ 1615-1499-1-1; **a)** lateral view, SEM Negative 3716, **b)** dorsal view SEM Negative 3732. **3a–d)** "*Zygobeyrichia*" n.sp. 2, aff. *Z. favaria* (Kummerow, 1953) sensu Groos-Uffenorde (1983) from Vinas section, Aragon, Spain, tecnomorph moulds from sample GZG GÖ 681-12. **3a–b)** Aristophot-photos of rv GZG Gö 681-12-211, L = 3.1 mm and H = 1.8 mm. **a)** external mould, **b)** internal mould, **3c–d)** SEM-photos of latex casts, **c)** lateral view of the latex cast of right valve figured in **3a**, **d)** ventral view of the latex cast from left valve GZG GÖ 681-12-212 (taken from Groos-Uffenorde, 1983, figure 2).

"*Zygobeyrichia*" *subcylindrica* (Rh. Richter, 1863) sensu lato (Figure 12: 1–4, 6, 7)

1863 *Beyrichia Kloedeni* M'Coy - Rh. Richter: 671, plate 19, figures 7–11

* 1863 *Beyrichia subcylindrica* n.sp. - Rh. Richter: 671–672, plate. 19, figures 12–15

1968 *Zygobeyrichia subcylindrica* (Rh. Richter, 1863) - Zagora: 13–15, text-figures 4, 5, plate 1, figures 1–3 (see synonymy)

1974 *Zygobeyrichia subcylindrica* (Rh. Richter) - Becker and Bless: 4, plate 1, figures 1–2

1979 *Zygobeyrichia subcylindrica* (Rh. Richter, 1863) - Gooday and Becker: 195

1980 *Zygobeyrichia subcylindrica* (Rh. Richter, 1863) - Weyant: 279–280

v 1982 *Zygobeyrichia subcylindrica* (Rh. Richter, 1863) - Groos-Uffenorde: 217, plate 3, figures 19–21

1982 "*Zygobeyrichia*" *subcylindrica* (Rh. Richter, 1863) - Becker and Groos-Uffenorde: 302–303, plate 1, figure 9

v 1983 "*Z.*" *subcylindrica* - Groos-Uffenorde: 344 (figure 4C), 348, 349

Figure 12. 1–4, 6–7) *"Zygobeyrichia" subcylindrica* (Rh. Richter, 1863) sensu lato from Early Devonian of Turkey (**1–5**, coll. Nazik). **1)** Internal mould of a right valve of tecnomorph, Korucuköy B section, DEVEC TR/E-25. **2)** Internal mould of a left valve of tecnomorph, Korucuköy B section, DEVEC TR/E-26. **3)** Latex cast of a right tecnomorph external mould, Korucuköy B section, DEVEC TR/E-27. **4)** Latex cast of a right heteromorph external mould, Korucuköy B section, DEVEC TR/E-28. **5)** "*Zygobeyrichia*" sp., internal mould of a left valve, Kabalakdere section, DEVEC TR/E-29. **6)** Three siltstone slabs from Yakadjik 6, labelled '*Beyrichia roemeri* Kayser' coll. Endriss 1908 (photos Helga Uffenorde 27/08/2014); **a)** tecnomorph internal mould of right valve, SMF Mbg. 7235, **b)** tecnomorph internal mould of left valve, SMF Mbg. 7234/2. **7)** External mould of a left valve on a fossiliferous siltstone slab, coll. Endriss, locality Yakadjik 1, SMF Mbg 7238. **8)** *Zygobeyrichia subcylindrica* vel *Zygobeyrichia devonica*, fossiliferous limestone slab from the Endriss collection (SMF), label 'Pendik/Bosporus, Dr. Endriss 1908' lateral view of two left valves; **a)** SMF Mbg. 7237/1, L = 4.6 mm, H = 2.4 mm, **b)** SMF Mbg. 7237/2, L = 4.9 mm, H = 2.3 mm. **9)** *Zygobeyrichia subcylindrica* vel *Gibba* ? *kayseri*, calcareous valves from Turkey (coll. Toula, GBA Vienna); **a)** left view (photo by I. Zorn 2014), Inv. Nr.: GBA 1900/002/0028, L = 7 mm and H = 3.9 mm, specimen of *Beyrichia roemeri* Kayser (1899), between Pendik and Kartal, **b)** right incomplete calcareous valve, photo AN 2421 (23 July 2014), Pendik-Kartal, E coast of Marmara sea. **10)** "*Zygobeyrichia*" *subcylindrica* (Rh. Richter, 1863) from the latest Early Devonian of Germany (Photo Hundertmark GZG Göttingen, DSC06084a), Orig. GZG 856-1291, coll. Helga Uffenorde 1981. Bedding plane with tectonically distorted external and internal moulds of tecnomorph and heteromorph specimens with accompanying tentaculites and brachiopods; the former clay pit Osterseifen, E of Olpe, Rhenish Schiefergebirge (the same layer was figured in Groos-Uffenorde, 1982), scale: the length of the dorsal border of the chonetid brachiopod is 18 mm.

v 1983 "*Zygobeyrichia*" *subcylindrica* - Groos-Uffenorde: 345

1986 *Zygobeyrichia* (recte *Arikloedenia*) *subcylindrica* (R. Richt.) - Přibyl: 79

1986 *Zygobeyrichia subcylindrica* - Zagora: 67, 71, photo 1

1991 *Zygobeyrichia subcylindrica* (Rh. Richter, 1863) - Becker and Bolz: 15, 20, 21–27, figures 3, 5–8

2012 *Zygobeyrichia subcylindrica* (Rh. Richter, 1863) (sensu stricto) - Becker and Franke: 92–93, figures 9–10

Characteristics: Large trilobate ostracodes with ventral connection of L_1 and L_3 interrupted below S_1, tubercle on L_2, heteromorphs with anteroventral crumina, tecnomorphs without alate structure, adventral structure with two rows of small tubercles.

Remarks: Because of the great variation in the distinctness of the lobation and the fact that only rare collections of external moulds show the tubercle on L_2 we use *Zygobeyrichia subcylindrica* [including *Zygobeyrichia devonica* (Jones and Woodward, 1889)] in a broad sense as mostly done.

The species was revised by Zagora (1968) based on new material from the latest Emsian of Thuringia (internal moulds of tecnomorphs and heteromorphs as well as silicified mostly juvenile valves).

Zygobeyrichia devonica (Jones and Woodward, 1889) is very closely related to, if not conspecific with, *Z. subcylindrica*.

It has yet to be verified if *Beyrichia armata* Richter (1863) is conspecific (Walther, 1907).

Arikloedenia zlichovensis (Přibyl, 1955) seems to be related to '*Zygobeyrichia* (recte *Arikloedenia*) *subcylindrica*' according to Přibyl (1986).

A detailed discussion on the group of *Zygobeyrichia subcylindrica* and on related forms named '*Zygobeyrichia* ssp., ex Gr. *Z. subcylindrica* (Rh. Richter 1963)' was summarised by Becker and Franke (2012). The specimens figured by Becker and Franke (2012) show variation in the distinctness of the lobation.

Zygobeyrichia roemeri (Kayser, 1899) is closely related but shows a reticulated surface and the tubercle on L_2 is unknown. The specimen from sample KOB-O3 is closely similar to *Cornikloedenina*.

Occurrences: '*Zygobeyrichia*' *subcylindrica* is well known from the European late Early Emsian to Latest Emsian. External and internal moulds are widespread in the Late Emsian shales and siltstones of Germany and sometimes very abundant on selected bedding planes (Groos-Uffenorde, 1982 and discussion in Becker and Bolz, 1991) and are shown in Figure 12: 10.

Turkish material: Kartal Formation in the Korucuköy B section and locality Yakadjik of the Endriss collection, Early Devonian.

***Zygobeyrichia subcylindrica* vel *Zygobeyrichia devonica* (Figure 12: 8)**

On a limestone slab with well-preserved crinoid ossicles, and tentaculites, two left calcareous valves of *Zygobeyrichia* (SMF label 'Pendik/Bosporus Dr. Endriss 1908') have also been found. They show an elongate distinct L_2, long and deep S_1 and S_2, and a weak ventral connection of L_2 and L_3, interrupted posteroventrally. Instead of the small tubercle on the distinct L_2 of the German *Z. subcylindrica*, this species has a bulbous respectively thickening of the dorsal part of the more elongate L_2.

***Zygobeyrichia subcylindrica* vel *Gibba*? *Kayseri* (Figure 12: 9)**

Rare specimens from Pendik-Kartal in the Toula collection (GBA Vienna) resemble individuals of *Z. subcylindrica* s.l. (including *Z. devonica*) and *G.*? *kayseri*. They are characterised by a distinct elevation on the ventral part of L_3 comparable to the calcareous valve of *Zygobeyrichia roemeri* sensu Kayser (1899). In contrast to the subdivided L_3 of *Gibba kayseri* this elevation is more elongate and weakly connected with the ventral lobe. Generic determination is not possible because heteromorphs are hitherto unknown.

***Zygobeyrichia onusta* (Kummerow, 1953) (Figure 13)**

? 1895 *Drepanella serotina*, Sandberger, MS, sp.n. - Jones: 66, plate 7, figure 12

v ? 1915 *Beyrichia tetrapleura* n.sp. - Fuchs: 77–79, plate 18, figures 11–12

1933 *Beyrichia tetrapleura* Fuchs, 1915 - Mauz: 279

v * 1953 *Kloedenia onusta* n.sp. - Kummerow: 33, plate 3, figure 6

pv 1964 *Zygobeyrichia onusta* (Kummerow) - Jordan: 34, plate 1, figures 1–3, plate 2, figure 8, plate 25, figure 5

1968 *Zygobeyrichia onusta* (Kummerow) - Sauer: 503–504, figure 2

v 1970 *Zygobeyrichia onusta* (Kummerow, 1953) - Groos and Jahnke: 45, plate 1, figures 2–4

1974 *Zygobeyrichia onusta* - Becker and Bless: 4, figure 1, 4

1979 *Zygobeyrichia onusta* (Kummerow, 1953) - Gooday and Becker: 195, figure 2

v ? 1982 *Zygobeyrichia onusta* n.sp. A - Groos-Uffenorde: 216, plate 2, figure 12, 14

1982 "*Zygobeyrichia*" cf. *onusta* - Becker and Groos-Uffenorde: 303, plate 1 figures 1–2

v 1983 "*Zygobeyrichia*" *onusta* - Groos-Uffenorde: 343, 349

? 1991 *Zygobeyrichia onusta* - Becker and Bolz: 14

2012 *Carinokloedenia onusta onusta* (Kummerow, 1953) - Becker and Franke: 91

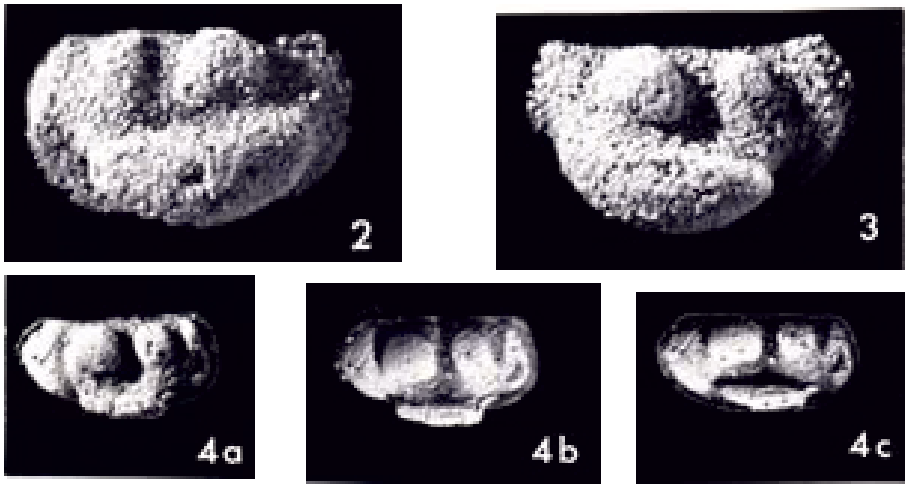


Figure 13. *Zygobeyrichia onusta* (Kummerow 1953) from the Eifel area/Germany taken from Groos and Jahnke (1970, plate 1, figures 2–4). **2)** Holotype, ZGI Berlin X 464 from Acheld near Oberstadtfeld. Lateral view, internal mould of a heteromorph right valve, L = 2.3 mm, H = 1.25 mm. **3)** Lateral view, internal mould of a heteromorph left valve from Acheld near Oberstadtfeld. **4)** Lateral views, internal mould of tecnomorph left valve from a road cut between Neroth and Oberstadtfeld.

Diagnosis: Relatively small trilobate beyrichiacean ostracode characterised by an indistinct L_1, prominent round L_2, elongate L_3 without cusp, tecnomorphs with narrow medioventral lobe, and heteromorphs with an inflated anteroventral to medioventral crumina.

Measurement: Holotype, heteromorph internal mould, L = 2.3 mm, H = 1.25 mm.

Remarks: Becker and Franke (2012) named Late Emsian specimens with an unsculptured, prominent L_2 and a carinated ventral lobe as *Carinokloedenia onusta carinata* n.subsp. Because *Carinokloedenia* is characterised by a sculptured and elongate L_2 and a more anterior position of the posterior end pointed crumina, we do not accept the generic determination of Becker and Franke (2012).

According to Jordan (1964), *Z. goslariensis* and *Z. onusta* are regional variations within the Rhenish facies. Sauer (1968) and Mauz (1933) reported very rare specimens with a striated crumina.

Occurrence: Late Middle Siegenian to early Late Emsian of the Rhenish Schiefergebirge and Eifel area/Germany. It sometimes occurs together with *Gibba schmidti*.

***Zygobeyrichia* sp., aff. *Z. onusta* (Kummerow, 1953) (Figure 14)**

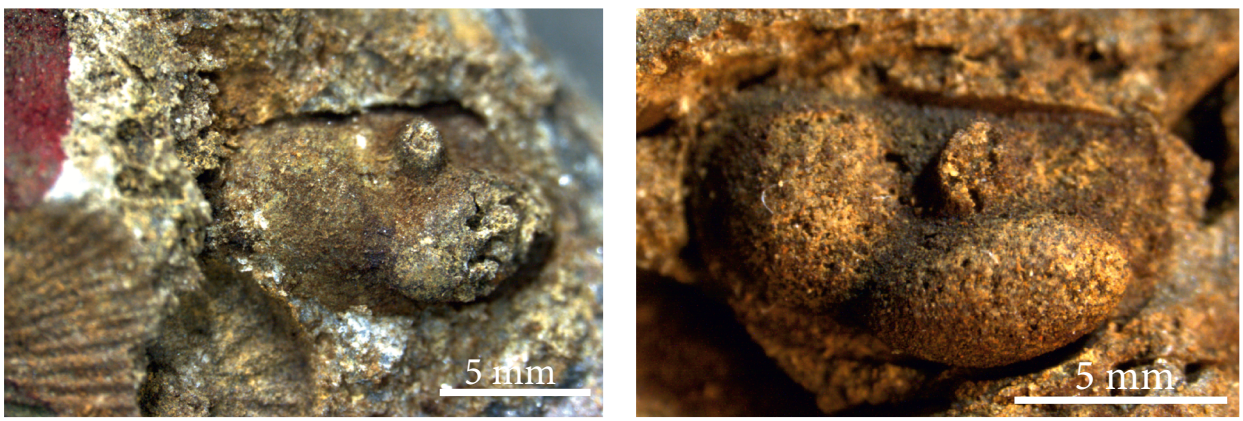


Figure 14. *Zygobeyrichia* sp., aff. *Z. onusta* (Kummerow, 1953). **1–2)** Lateral view, internal mould of a heteromorph right valve, coll. Nazik, Kabalakdere section. **1)** DEVEC TR/E-30, **2)** DEVEC TR/E-31.

Remarks: Some internal heteromorphic moulds in the new collection from Turkey (coll. A. Nazik) are related to *Z. onusta*, but L_2 and L_3 are much smaller (e.g., Figure 14: 1). The outline, the shape of L_2, and the position of the crumina seem to be like *Z. onusta* (e.g., Figure 14: 2), but the posterior lobe L_3 is more inflated and seems to be dorsally pointed in the specimen (Figure 14: 2, DEVEC TR/E-31). The crumina is more distinctly separated from the lobes, as in the larger *Z. subcylindrica*.

Material: Kabalakdere section, e.g., DEVEC TR/E-30, DEVEC TR/E-31 (Figure 14: 1, 2).

Occurrence: Findikli Formation, Earliest Early Devonian, Lochkovian.

Beyrichiid gen. et sp. indet. (Figures 15a–15d)

There are beyrichiacean ostracodes with a subamplete outline and three elongate lobes L_1–L_3. The species is characterised by the L_1 subdivided into two lobules. L_2 and L_3 distinctly elongate and nearly straight, distinct narrow rim parallel to posterior border, S_1 and S_2 very long. The distinct horizontal ventral lobe (= alate structure?) does not overreach the marginal rim.

Remarks: Hitherto no female specimens have been found and therefore its affinity to various Silurian and Early Devonian beyrichiacean ostracode species is very difficult to discern. Therefore, we use open nomenclature for this genus.

Very similar to the smaller new Turkish specimens is the large but distorted mould of *Nodibeyrichia gedanensis* (Kiesow, 1884), in Schallreuter (2000), collected from the Köbbinghausen Formation (Pridoli/latest Silurian) near the type locality of *Gibba spinosa* from the Hüinghausen Formation (Gedinnian/earliest Devonian) of the Rhenish Schiefergebirge/Germany. This poor material of Schallreuter is characterised by the presence of two knobs on the ventral part of the syllobium.

The lobation of the carinokloedeniines from the Early Devonian of Maine/USA (Berdan, 1983) is similar but their L_1 is not subdivided into lobules and the lobes have carinae.

The L_2 and L_3 of *Nodibeyrichia* sp. of Berdan (1983) are less elongate and the syllobium is curved and not horizontal like the alate structures, and the lobes of *Carinokloedenia*

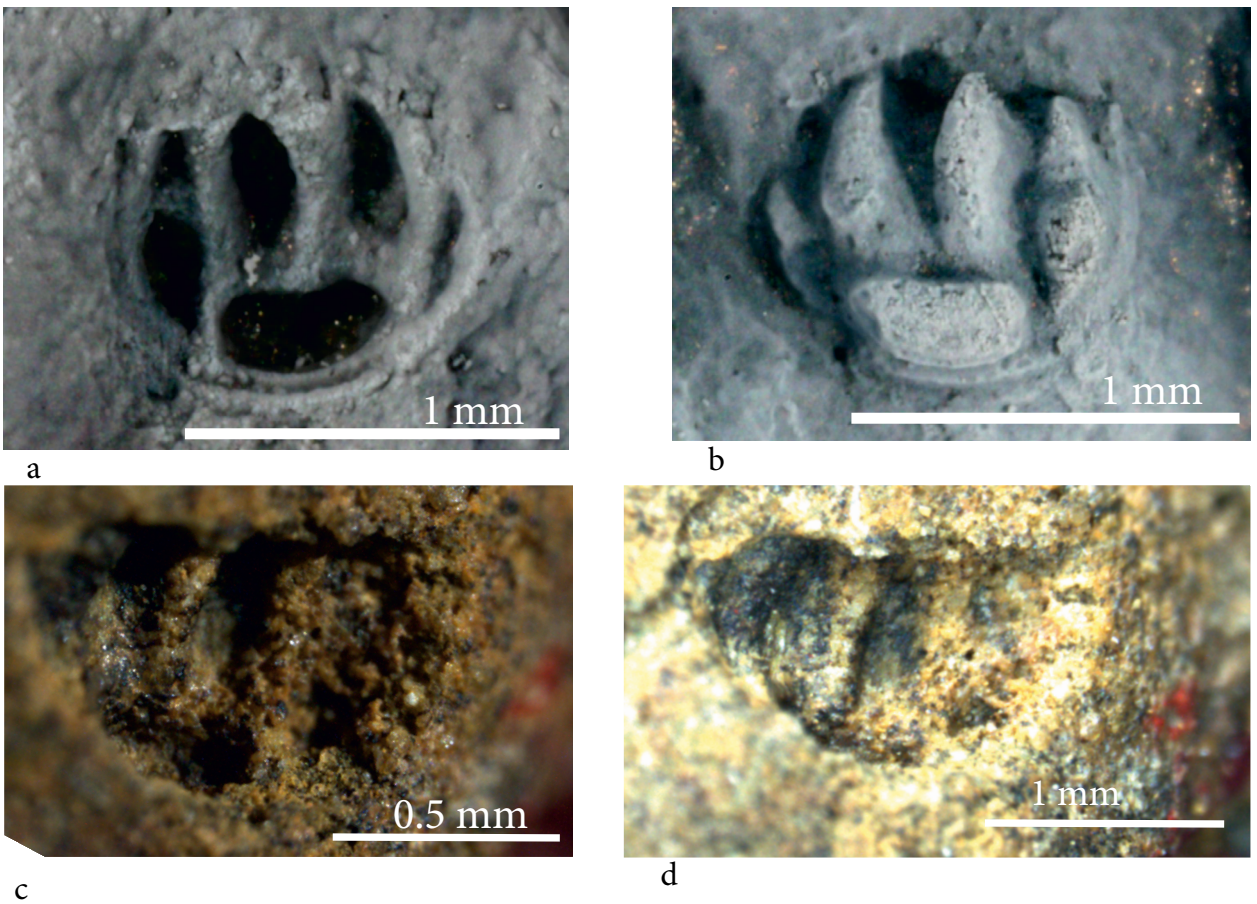


Figure 15. Beyrichiid gen. et sp. indet., coll. Nazik, Kabalakdere section. **a)** Right valve, external mould, DEVEC TR/E-32, **b)** latex cast of external mould of right valve, DEVEC TR/E-33, **c)** right valve, external mould, DEVEC TR/E-34, **d)** right valve, external mould, DEVEC TR/E-35.

? sp. (Berdan, 1983) are more elongate and carinated. Both the latest Silurian species were reported from the Baltic-British province of Maine/USA.

'*Zygobeyrichia*' sp. B, aff. *Z. kayseri* sensu Groos-Uffenorde (1983) is characterised by three ventral lobules; that is, the posterior lobe is as clearly subdivided into two lobules.

Occurrence: Kabalakdere section (Figure 4), sample numbers: Ka-O2, Ka-O3, Ka-O4, Ka-O5, Ka-Ma 7 m. Fındıklı Formation, Early Devonian (Lochkovian) of NW Anatolia.

5. Biostratigraphical remarks and regional distribution

The localities of the Toula collection (Kayser, 1899; deposited in Vienna) and of the relatively large collection of Endriss (e.g., Hüffner, 1918; now deposited in Frankfurt) from north-western Turkey are not very precisely given and their exact stratigraphic position is unknown. Before the detailed research of Paeckelmann (1925, 1938) the biostratigraphy was based on lithostratigraphic comparison (e.g., correlating the terrigenous sediments of the NW Turkey with those of Germany). These outcrops cannot be studied anymore because they are inaccessible.

The new collections of beyrichiacean ostracodes made by Atike Nazik are placed in the detailed stratigraphical column of the Korucuköy B and the Darlik sections (Kartal Formation) from the Şile-İstanbul region and of the Kabalakdere section (Fındıklı Formation) from the Çamdağ-Zonguldak region (Figures 2–4).

Brachiopods from the first 50 m of the Fındıklı Formation of the Kabalakdere section are *Howellella* sp., *Howellella* cf. *mercurii*, *Schizophoria* sp., *Protocortezorthis* cf. *fornicatimcurvata*, *Eoschuchertella* sp., and *Eoschizophoria* cf. *fragilis* and these faunas indicate a Lochkovian age (Yalçın and Wilde, 2009). Conodont taxa have been determined in the beyrichiacean-bearing levels of the Kabalakdere Section (Boncheva et al. 2009; Yılmaz et al. 2015) and dated as Lochkovian to Pragian.

In the first 100 m of the Kartal Formation of the Korucuköy B Section (around Korucuköy-Şile) the macrofossils *Leptadonta clausa*, *Brachyspirifer crassicosta*, *Mesoleptostrophia* sp., *Megastrophia* sp., *Hysterolites* sp., *Vandercammenina* cf. *trigeri*, *Cryptonella* sp., *Rhenoschizophoria* sp., *Pleurodictyum constantinopolitanum*, and *Zaphrentis* sp. were found together with beyrichiacean ostracodes (Nalcıoğlu et al., 2009; Yalçın and Wilde, 2009). *Cymostrophia* (*Protocymostrophia*) sp., *Schizophoria* ? sp., atrypid brachiopods, and *Zaphrentis* sp. were identified in first 15 m of the Darlık Section around Ömerli Dam Lake.

Conodonts are still lacking to facilitate detailed biostratigraphy in the Turkish beyrichiacean-bearing levels of the Kartal Formation, but based on brachiopods and other macrofossil groups these levels are dated as late Early Devonian, most probably Emsian. The new records of large beyrichiacean ostracodes from the Kartal Formation are in accordance with the European occurrences, e.g., *Gibba schmidti* and *Zygobeyrichia subcylindrica*.

Hitherto, no well-dated Lochkovian to Pragian (respectively Gedinnian to Siegenian) beyrichiacean successions were known. The new beyrichiacean ostracodes of the Fındıklı Formation are also not suitable for detailed biostratigraphy.

6. Discussion and conclusion

The existing information on the Early Devonian beyrichiacean ostracode faunas was summarised, e.g., by Polenova (1971), Groos-Uffenorde (1983), Berdan (1990), and Becker and Franke (2012). The Palaeozoic benthic shallow-water and world-wide distributed ostracode faunas may be used in intercontinental correlation and palaeogeographical reconstructions (Schallreuter et al., 1985; Siveter, 1989; Vannier et al., 1989; Crasquin-Soleau et al., 2001; Crasquin-Soleau and Kershaw, 2005; Becker and Braun, 2008; Dojen, 2009; Perrier and Siveter, 2013; Olempska et al., 2015).

In the reconstruction of Cocks and Torsvik (2006), the Turkish Pontides were situated at some distance from the northern African part of Gondwana, between the Adria and Hellenic Moesia in the Early Devonian (Emsian, 400 Ma). The palaeogeographical reconstruction of Early Devonian time by Paris and Robardet (1990) shows a wide area of continental shelves and slopes in the north-east of Gondwana south of the Rheic Ocean. Many localities with large beyrichiacean ostracodes occur in this area, but the position of important localities from Laurussia, like those, e.g., in Podolia and Germany, are separated from those from Gondwana and peri-Gondwana by the Rheic Ocean (Figures 16A and 16B; Table).

The large benthic beyrichiaceans like *Gibba* and *Zygobeyrichia* are known from shallow-water sediments of the Early Devonian of the Rhenish Schiefergebirge (Germany), Ossa Morena Zone, Celtiberia, Armorica, northern France, Bohemia, North Africa, and NW Turkey. Therefore, those areas were probably not separated by deep-water areas, as shown, e.g., in the reconstruction of Cocks and Torsvik (2006). The same applies to the brachiopods, because several brachiopod genera were found north and south of the "Rheic Ocean" (Jansen et al., 2014a, 2014b).

Dojen (2009) showed possible migration paths of beyrichiacean ostracodes using the reconstruction of Cocks and Torsvik (2006) and surmised shallow-water connections between Laurussia, Gondwana, and peri-Gondwana and questioned the presence of the Rheic Ocean in Late Silurian to Early Devonian time; this is in accordance with our interpretation.

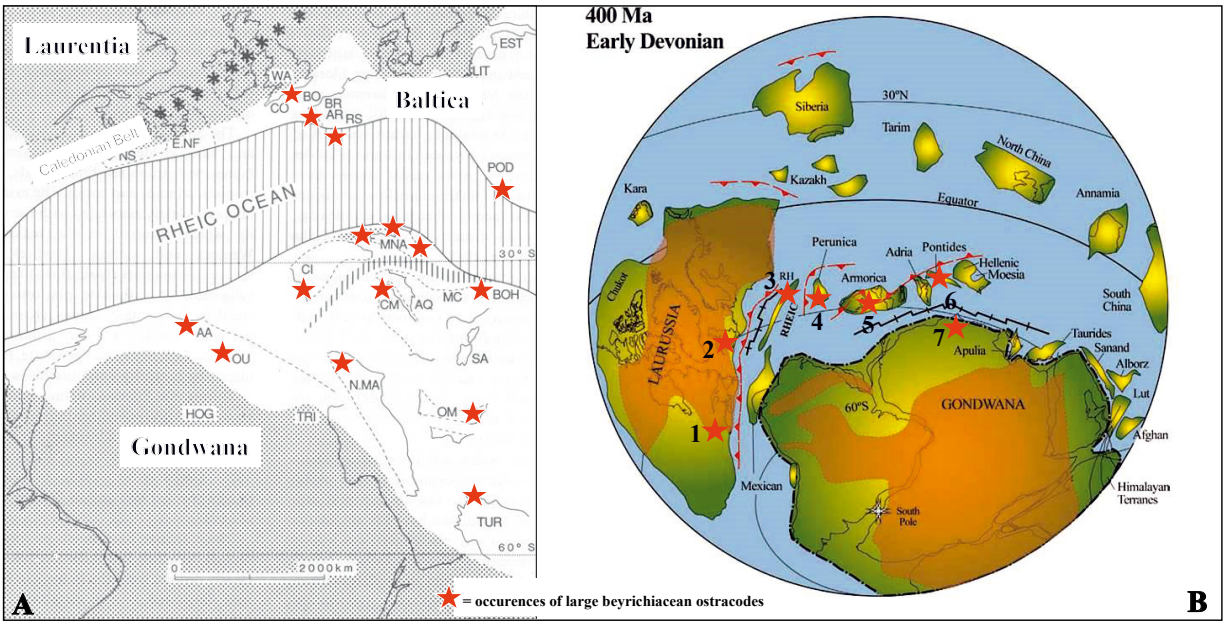


Figure 16. Occurrences of large beyrichiacean ostracodes in the Early Devonian of Europe and North Africa. **A**) Plotted on the map from Paris and Robardet (1990) (for abbreviations see Table, column d). **B**) Plotted on the map of Cocks and Torsvik (2006), 1. Laurentia (North America), 2. Baltica (SW England), 3. Rheno-Hercynian Terrane, 4. Perunica (Bohemia), 5. Armorican Terrane (France and Spain), 6. Pontides (Northern Turkey), 7. Gondwana (Morocco, Algeria).

Olempska et al. (2015) described new silicified Early Devonian non-beyrichiacean ostracodes from the western Pontides/İstanbul Terrane and discussed the different reconstructions of the palaeogeographic positions and concluded a peri-Gondwanan (Avalonian) setting of the Pontides during Devonian time.

Even studies of late Early Devonian non-beyrichiacean ostracodes from Morocco (SW Anti-Atlas) by Becker et al. (2004) supported the statement, e.g., of Balinski et al. (2002), who did not support the idea of wide oceanic separations of Laurussia and Gondwana at that time.

The new studies on the Turkish beyrichiaceans complete the old collections (e.g., of Toula and Endriss) from localities in the former outskirts of Constantinople, which are now inaccessibly covered by the city of İstanbul. Many additional internal moulds of large beyrichiacean ostracodes have recently been found but well-preserved external moulds are still very rare and therefore exact determinations are still difficult.

The new beyrichiacean ostracodes from the Early Devonian of the NW Anatolia area indicate nearshore positions in a terrigenous environment. Because of the relatively complete nature of the preservation of the valves, long-distance transport is not envisaged for them.

The new Turkish beyrichiacean faunas show clear affinities to contemporaneous ostracode faunas from northern Europe (e.g., France and Germany), Bohemia, Podolia, Spain, and Morocco. A shallow water connection of those areas in Early Devonian time is supported and a wide separation of Laurussia and Gondwana seems unlikely. However, questions regarding if and how the large benthic beyrichiacean ostracodes could cross an ocean or deep-water areas and how wide and deep the presumed Rheic Ocean was in Early Devonian time remain unresolved.

Acknowledgements

This study was supported by TÜBİTAK/Turkey (Project No. 104Y218), BMBF/Germany (Project No. TUR04/009), IGCP-499, and the Çukurova University Scientific Research Projects Coordination Unit (Project No. MMF2012BAP4). This study would not have been possible without the help of project leaders Prof. Dr. M. Namık Yalçın and Dr. Volker Wilde. The first author would like to thank the Geoscience Centre University of Göttingen (GZG, Department of Geobiology and Museum) and the Senckenberg Museum Frankfurt for providing access to ostracode collections and literature. The first author is also grateful to DAAD, Germany, for supporting this research (Referat: 316).

Eberhard Schindler, Alan Lord, Steffi Hirschmann, Claudia Franz, Michael Ricker, and Olaf Vogel (all of Senckenberg Museum and Forschungsinstitut Frankfurt) and Irene Zorn (GBA Vienna) are thanked for their help with access to the collections and with photography and preparation of some beyrichiacean ostracodes in the Endriss collection, Frankfurt, and the Toula collection,

Table. Occurrences of Early Devonian ostracodes and main references for large beyrichiacean ostracodes of Europe and North Africa. a = numbers in Groos-Uffenorde (1983); b = abbreviation in Robardet et al. (1991); c = numbers in Dojen (2005); d = abbreviation in Paris and Robardet (1990) (Baltica: blue, Gondwana: brown).

a	b	c	d	Occurrences of Early Devonian ostracodes and main references on large beyrichiacean ostracodes
1983	1991	2005	1990	
1	--	24	**WA, CO**	SW-England/Baltica: Jones and Woodward (1889), Jones (1890)
2	NO	1		Normandy: Weyant (1966)
3	BR	2, 3		Armorican Massif/Brittany: Gayet (1965), Weyant (1980), Groos-Uffenorde (1983)
19	BO	23	**BO**	Boulonnais, Artois: Barrois et al. (1922), Groos-Uffenorde (1986)
18	AR,SL	21	**AR, RS**	Ardennes and Rhenish Schiefergebirge: Kummerow (1953), Jordan (1964), Stoltidis (1972), Groos-Uffenorde (1982, 1983), Becker and Franke (2012)
18	EL	21		Eifel: Sauer (1968), Becker and Bless (1974), Gooday and Becker (1979), Becker and Bolz (1991), Becker and Groos-Uffenorde (1982)
17	HZ	22		Harz: Eichenberg (1931), Dahmer (1951), Jordan (1964), Groos and Jahnke (1970)
16	FR	20		Frankenwald, Thuringia: Richter (1863), Jordan (1970), Zagora (1968)
12	--	16	**POD**	Podolia: Abushik (1971)
11	--	15		Moldavia: Abushik and Trandafilowa (1977)
4,5	CA	4–6	**CM**	Cantabrian Mountains: Groos-Uffenorde (1983), Becker (1996)
6	--	--		Eastern Pyrenees
7	--	11		Mouthoumet Massif
8	MN	12		Montagne Noire
9	AC	13		Carnic Alps
13	--	17		Poland: Nehring (1973), Nehring-Lefeld (1985)
14	--	18		Moravia: Chlupac et al. (1968)
15	BH	19	**BOH**	Bohemia/Perunica: Příbyl (1952, 1955, 1987)
x	CI	7	**CI**	Celtiberia: Groos-Uffenorde (1983), Lethiers and Raymond (1993), Dojen (2004, 2005)
--	--	9	**AA, NMA**	Morocco: Termier and Termier (1950), Vannier (1994)
--	--	10	**OU**	Ougarta, Algeria: LeFèvre (1963, 1967, 1971)
x	ZOM	8	**OM**	Sierra Morena/S Spain: Groos-Uffenorde (1983, 1991)
10	--	14	**TUR**	Turkey/Pontides: Kayser (1899), Leidhold (1918), Paeckelmann and Sieverts (1932), Paeckelmann (1938)

Vienna. The biostratigraphical data of the brachiopod collections of Ulrich Jansen/SMF and Gonca Eroğlu (MTA Museum) are acknowledged. The authors thank the reviewers Prof. David J. Siveter, Prof. Ewa Olempska, and Dr. Claudia Dojen very much for their helpful comments and linguistic corrections.

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