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

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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 Istanbul area, including the Toulia 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 schmidtii, 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 Istanbul 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 Istanbul 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;
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 Istanbul 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), Önal (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/Bosphorus Dr. Endriss 1908; Tuzla/Bosphorus Dr. Endriss 1908; Yakakıck, Endriss 1908 (= Yakacık); Therapia am Bosphorus, coll. Endriss (= Tarabya); Kanlıydscha, Toula 1895 (Kanlıyda = Kanlıca); and Pendik-Kartal, Toula 1895.

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

3.2.1. Darlık Section

The study section 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).

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 fissiliferous limestones. Twenty-nine samples were examined for
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
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.
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 L2 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) = Aechnina spinosa in Jones and Holl, 1869

58–59 (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

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
1987 Carinokloedenia (Carinokloedenia) Abushik, 1971– Přibyl: 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
Type species: Beyrichia (Gibba) spinosa Fuchs, 1919
Characteristics: Large trilobate beyrichiacean ostracodes characterised by a rim around a prominent L2. 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 Přibyl, 1987

Gibba (Gibbula) Schallreuter, 1996 = Gibba (Schoeningibba) in Schallreuter (1998)
Gibba (Joachimokloedenia) Přibyl, 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, L1 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
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

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’.

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 $L_1$. 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 heteromorphic internal mould was cited by Groos-Uffenorde (1982) from the slab SMF Mbg. 363 with ‘Beyrichia roemerii 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 roemerii 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 $L_2$ 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.


Remarks: The species is characterised by a differentiation of the ventral lobe into 3 elongate lobules below the short $L_1$ and $L_2$, and the oval $L_3$. 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


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

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 schmidtii.

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


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
v 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 reidescbachensis 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 Toulou in Vienna) from Kanlica: 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’ 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.

**Diagnostically important features** are the lobate valves with prominent carinated L, and long adductoral sulcus (S,) 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 (L2) and is only visible in external 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 (L2) 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).

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


**Stratigraphical distribution:** Early Devonian.

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

**Zygobeyrichia Ulrich, 1916**

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, and L, (zygal ridge).

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

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

According to Berdan (1972), the crumina of *Lophokloedenia* 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.

**Occurrence:** 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, 1889) (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
*n. 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 Beyrichia 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 (Zy gobolba?) roemeri Kayser - Bassler and Kellett: 205
1935 Beyrichia roemeri Kayser - Dahmer: 139
?? 1935 Beyrichia Roemeri Kayser - Péneau: 45–47, figure 2
1938 Beyrichia roemeri Kayser - Paeckelmann: 26, 27, 55, 61, 65, 66, 72, 85, list p. 90, 104, 105, 107, 108, 111, 113
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 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 L2. The distinctness and size of the L1 and L3 varies and they may be weakly connected ventrally with the L2. The L1 and L3 are less pronounced in juveniles. The surface of the valve is finely reticulated to distinctly granulated. A tubercle on the L2 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 L2 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 *Beyrichia 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 L₁ and L₂. 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.

Pénéau (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 Darlık 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 * 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 L₁ (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 L₂.

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 L₁. The L₁ and L₂ are ventrally only weakly connected. The difference from *Z. favaria* is the much more pronounced ventral part of L₁, 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.
"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 Yakadık 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 Yakadık 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 Gross-Uffenorde, 1982), scale: the length of the dorsal border of the chonetid brachiopod is 18 mm.
but shows a reticulated surface and the tubercle on L 2 is figured by Becker and Franke (2012) show variation in the summarised by Becker and Franke (2012). The specimen (Rh. Richter 1963) was Z. subcylindrica according to Pähril (1986).

related to ’Zygobeyrichia (recte Arikloedenia) subcylindrica (R. Richt.) - Pähril: 79

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


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 2; 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 1, 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 (Pähril, 1955) seems to be related to ’Zygobeyrichia (recte Arikloedenia) subcylindrica’ according to Pähril (1986).


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/Bosphorus 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 1, 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 1, comparable to the calcareous valve of Zygobeyrichia roemeri sensu Kayser (1899). In contrast to the subdivided L 1, 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 Kloedia 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
2012 Carinokloedenia onusta onusta (Kummerow, 1953) - Becker and Franke: 91
Diagnosis: Relatively small trilobate beyrichiacean ostracode characterised by an indistinct L1, prominent round L2, elongate L3 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 L2 and a carinated ventral lobe as *Carinokloedenia onusta carinata* n.subsp. Because *Carinokloedenia* is characterised by a sculptured and elongate L2 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)
Remarks: Some internal heteromorphic moulds in the new collection from Turkey (coll. A. Nazik) are related to *Z. onusta*, but L₁ and L₂ are much smaller (e.g., Figure 14: 1). The outline, the shape of L₂, and the position of the crumina seem to be like *Z. onusta* (e.g., Figure 14: 2), but the posterior lobe L₃ 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 L₁–L₃. The species is characterised by the L₁ subdivided into two lobules. L₂ and L₃ distinctly elongate and nearly straight, distinct narrow rim parallel to posterior border, S₁ and S₂ 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 L₁ is not subdivided into lobules and the lobes have carinae.

The L₁ and L₂ 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*

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**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.
The localities of the Toulá collection (Kaysér, 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 Darlık sections (Kartal Formation) from the Şile-Istanbul 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., Eoschuchertella sp., Protocortezorthis cf. fornicatimcurvata, Eoschuchertella sp., and Eoschizophoria cf. fragilis and these faunas indicate a Lochkovian age (Yağcı 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., Megastraphia 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; Yağcı 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 schmidtii and Zygobeyrichia subcilindrica.

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; Olemska 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.
Olempska et al. (2015) described new silicified Early Devonian non-beyrichiacean ostracodes from the western Pontides/Istanbul 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 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.


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.

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### Table

Occurrences of Early Devonian ostracodes and main references for large beyrichiacean ostracodes of Europe and North Africa.

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