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Source: Acta Palaeontologica Polonica, 61(1) : 51-70

Published By: Institute of Paleobiology, Polish Academy of Sciences

URL: https://doi.org/10.4202/app.00061.2014
Rugose corals across the Devonian–Carboniferous boundary in NW Turkey

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An uppermost Famennian (Strunian) coral assemblage has been recovered in the middle part of the Yılanlı Formation of the Istanbul Zone (Zonguldak and Bartın areas, NW Turkey). In the Bartın area, the studied fossiliferous interval corresponds to a c. 30 m-thick unit of bioclastic to peloidal wackestone to packstone grading to grainstone and including two stromatoporoid biostromes. In the Zonguldak area, 60 km westward, the bioclastic facies is dominant. The rugose corals are mainly solitary taxa belonging to the genera *Campophyllum*, *Bounophyllum*, *Amplexocarinia*, and *?Metriophyllum*, and only one colonial genus occurs: *Pseudoendophyllum*. This fauna is similar to that documented in Europe. The campophyllids and dibunophyllids are the main component of the uppermost Famennian assemblages in S Belgium, N France, W Germany, NW and S Poland. The endophyllids occur in S Poland, Novaya Zemlya, and in the Ural Mountains. The Istanbul Zone is supposed to be situated in the central part of the Palaeotethys Ocean, along the southern margin of Laurussia during the uppermost Devonian and Carboniferous. The rugose corals indicate some relationship with the eastern part of Laurussia, or that both areas were under a common marine influence at this time. The global Hangenberg event was not recognized in the Turkish localities, except for the disappearance of the corals, occurring less than 19 m below the Devonian–Carboniferous boundary based on the foraminifers. There is no major facies change through the boundary and the first Carboniferous corals (small *Uralinia* and *Caninophyllum*) appear 6 m above the D–C boundary. The new species *Caninophyllum charli* sp. nov. is described from the upper part of the lower Tournaisian.

Key words: Rugosa, palaeobiogeography, Hangenberg event, Strunian, Hastarian, Famennian, Tournaisian, Turkey.

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Received 15 January 2014, accepted 25 September 2014, available online 7 October 2014.

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Introduction

The uppermost Famennian (Strunian) was a transitional period between the slow faunal recovery following the Frasnian–Famennian crisis and the ecological crisis associated with the Devonian–Carboniferous boundary. It was also a period of rapid diversification of corals probably linked with the Strunian transgression prefiguring the Lower Carboniferous high sea level that followed the worldwide low sea level of the Famennian. During this transgressive phase, several events occurred, among which the Hangenberg is the most important because of the associated extinctions. This biotic event is recognised as one the six largest mass extinctions in geological times. The origin of the crisis is still debated but eustatic and climatic changes resulting in perturbations in the carbon cycle are suggested as the main causes (see Kaiser et al. 2008, 2010 and references therein for recent compilation). The Hangenberg event is often associated with the deposition of euxinic black shale in basin and shelf facies, and a common positive shift of δ¹³C_carb (Kumpf et al. 2014 for recent review). The crisis strongly affected the marine ecosystems with severe losses within the ammonoids, trilobites, conodonts, ostracods, foraminifers, tabulate, and rugose corals, and the total extinction of the stromatoporoids and placoderm fishes (Kalvoda 1986; Korn 1986; Simakov 1993; Benton 1993; Walliser 1996; Poty 1999; Nicollin and Brice 2004). The modalities of radiation and extinction of rugose corals at the Devonian–Carboniferous boundary were documented by Poty (1999) and Berkowski (2001, 2002) based mainly on data from Europe, South China, and Eastern Siberia. In the Middle East, uppermost Famennian corals were unknown but shallow water carbonates were documented by Dîl (1975) and Dîl et al. (1976) in the Istanbul Zone (NW Turkey).
Turkey), within the Yılanlı Formation. The recent investigation of Dîl’s localities (Dîl 1975; Dîl et al. 1976) yielded an abundant coral fauna and associated foraminifers. The aims of this paper are (i) to document sections covering the Devonian–Carboniferous boundary in NW Turkey and (ii) to describe the uppermost Famennian (Strunian) and lower Tournaisian (Hastarian) rugose corals from these sections. The new data allow a comparison of the faunal assemblage of Turkey with some previously described rugose coral faunas of Eurasia.

In Western Europe, the uppermost Famennian is often synonymised with the term “Strunian”. Initially, “Strunian” was used in a time-facies sense (fossiliferous marine carbonate facies overlying the siliciclastics of the Middle–Upper Famennian). The term is currently used in a stratigraphic way only and corresponds to the uppermost Famennian (fourth and last substage of the Famennian) that covers the upper Palmatolepis expansa and Siphonodella praesulcata conodont zones (Conil et al. 1986; Streel et al. 2006). Similarly, the lower Tournaisian substage, defined in Belgium as “Hastarian” and its sequence-, litho-, and bio-stratigraphic identity (Poty et al. 2013) can be recognized in NW Turkey. Since no stratigraphic scheme is available in Turkey, the stratigraphic canvas of Poty et al. (2006), established for Western Europe succession, was successfully applied.
Institutional abbreviations.—PA.ULg, Laboratory of Animal and Human Palaeontology, University of Liège, Belgium; IPG, Institute of Palaeontology and Geology, Nanjing, China.

Other abbreviations.—G.xx (Zonguldak 2008/2011, Gökğöl section), ET.xx (Bartin 2010/2011, Topulca section), D.xx (Bartin 2010, Dallıca section), EV.xx (Bartin 2010, Esenpinar section); D–C, Devonian–Carboniferous; DFZ, Devonian foraminiferal zones of Poty et al. (2006); LS, longitudinal section; MFZ, Mississippian foraminiferal zones of Poty et al. (2006); TS, transverse section.

Geological setting and description of key sections

The Istanbul Zone is classically divided into Istanbul and Zonguldak areas. During the Late Devonian and Early Carboniferous times, the Istanbul Zone was part of the Laurasian southern margin and had been drifting southward during the Albian when the Western Black Sea Basin opened (Görür 1988). Its former location was demonstrated by the similarity of the tectonostratigraphic records of the zone with the Moesian terranes (see Görür et al. 1997 and Kalvoda and Bábek 2010 for a recent review). In the Istanbul Zone, the D–C transition is situated within the Trakya flysch series (Özgül 2012 and references therein). In the Zonguldak Zone (Zonguldak and Bartın areas; Fig. 1), the Devonian and Carboniferous carbonate rocks are included in the Yılanlı Formation. The D–C transition is exposed in the Gökgöl section (Zonguldak vicinity) and in the Topulca, Dallıca, and Esenpinar sections (Bartin vicinity).

The Gökgöl section is situated along the road D750 Devrek-Zonguldak, upstream of the Asma hamlet, 4 km south of Zonguldak (41°26'19.28" N 31°50'05.43" E; Fig. 1C: G). The uppermost Famennian is dominated by thick-bedded bioclastic floatstone containing fragments of stromatoporoids, solitary rugose corals (Campophyllum), syringoporids, and Pseudochaetetes. This 3 m-thick fossiliferous horizon (G3) is overlain by a 15 m-thick unit (G7a) composed...
of pluri-metric (?) massive beds of light dolomitic limestone with no macrofauna (Fig. 2). Several horizons yielded a rich association of foraminifers, including numerous quasiendothyrids indicating the Strunian DFZ7 biozone of Poty et al. (2006). The following 10 m (unit G7b) are dolomitic and non fossiliferous. The G7c unit is dominated by massive light bioclastic limestone (packstone and grainstone) that yielded a foraminiferal fauna typical of the MFZ2 biozone of Poty et al. (2006). The D–C is thus situated within the G7a–c interval (Fig. 2). By comparison with the Topluca section (see below), the boundary should be placed in the lower part of the G7a sub-unit. Unfortunately, the sampling was not detailed enough and the frequent dolomitization often hides the microfossils useful for the boundary identification. The next unit (G8) is marked by the appearance of small black cherts and the progressive darkening of the limestone. The sub-unit G8a (c. 20 m-thick) is dominated by thinly bedded crinoidal and bioclastic limestone (mainly packstone) with brachiopods shells layers and small cherts. The overlying unit shows similar microfacies but the black cherts are less frequent and some horizons with corals (Caninophyllum and syringoporids facies) were noticed. Its top is dolomitized and capped by an erosive surface. Foraminifers from the G8b fossiliferous level indicate the MFZ3 biozone, i.e., the upper part of the Lower Carboniferous (Fig. 2). The Gökgöl section exposes almost continuously the Tournaisian and Viséan succession (Dîl 1975; Dîl et al. 2006). The D–C is thus situated in the following 25 m that were analysed in detail (Fig. 4). Beds 1 to 10 still contain Campophyllum and stromatoporoids in bioclastic facies. Beds 11 to 16 still yielded Devonian foraminifers (DFZ7). Beds 17 to 32 are dolomitized and the original facies are not recognizable. Bed 33, less dolomitized, yielded the last Devonian foraminifers (Quasiendothyra; DFZ7). Beds 35–40 yielded only unilocular foraminifers, typical of the lowermost Hastarian MFZ1 biozone. The D–C boundary is placed at the top of bed 33 after the foraminifers. The next unit begins with 4 m of light grey argillaceous nodular limestone containing small black cherts but no corals (Fig. 2). A gap of 12 m separates this unit from the following one, composed of light grey limestone, finely bioclastic with Urainia simplex, the first Carboniferous coral recorded in Topluca. The next 10 m are massive light-coloured limestone that yielded only fragments of brachiopods.

The Dallıca section is composed of a series of small outcrops along a forestry path north of the Akgöz hamlet (41°40′09.58″ N 32°18′34.68″ E; Fig. 1D: D). The uppermost Famennian is represented by light-coloured limestone with small colonies of Pseudoendophyllum sp. and cauliflower-shaped stromatoporoids. The foraminifers are not diversified but the occurrence of the genus Avesnella allows the identification of the DFZ5–6 biozones of Poty et al. (2006), i.e., the lower part of the Strunian. The quality of the outcrops was not appropriate for logging.
The Esenpınar section is also a succession of small outcrops along the road from Esenpınar hamlet to Bartın. The uppermost Famennian crops out approximately 1.5 km west of the hamlet (41°41'13.11" N, 32°15'26.22" E; Fig. 1D: E). The facies are bioclastic and pelloidic and the faunal content includes *Campophyllum*, syringoporids, and stromatoporoids.

**Material and methods**

The present paper is based on c. 80 specimens collected in Zonguldak and Bartın areas between 2008 and 2011 and studied in thin section (c. 180 transverse and longitudinal thin sections). The newly collected material is housed at PA.ULg.


**Systematic palaeontology**

Class Anthozoa Ehrenberg, 1934
Subclass Rugosa, Milne-Edwards and Haime, 1850
Order Stauriida Verrill, 1865
Suborder Cyathophyllina Nicholson in Nicholson and Lydekker, 1889
Family Campophyllidae Wedekind, 1921
Genus *Campophyllum* Milne-Edwards and Haime, 1850

*Type species*: *Cyathophyllum flexuosum* Goldfuss, 1826; Strunian of Stolberg (Aachen, Germany).

*Emended diagnosis*—Cylindrical solitary corallum. Major septa long (2/3 of the corallum radius), extending or not to the axis, straight or sinuous, sometimes carinated. Minor septa long, usually carinated. Cardinal fossula conspicuous. Dissepimentarium narrow to wide, including concentric interseptal dissepiments and occasional lonsdaleoid dissepiments. Tabulae complete, mesa-shaped. Emended from Hill (1981).

**Remarks**—According Hill (1981), *Campophyllum* is the only member of the family Campophyllidae, nevertheless, “*Palaeosmilia* aquisgranensis” (Frech, 1885) could be included in the same family as it probably evolved from *Campophyllum* (and has no affinity with the Viséan *Palaeosmilia*; see Poty 2010). Goldfuss’ (1826) type material of *Campophyllum flexuosum* was considered by this author as Middle Devonian. Schindewolf (1937) and Frech (1885) considered them as Strunian, a view shared by Hill and Jull (1965) in their re-description of Goldfuss’ types. Hill and Jull’s (1965) paper allowed the definition of the genus to be restrained to Strunian forms. Middle Devonian and Viséan corals attributed to *Campophyllum* should therefore be reinterpreted. *Campophyllum* were described is the Namur-Dinant Basin (Belgium, Aachen)...
the morphology of "Campophyllum" by Sorauf (1992) show several morphological differences (minor septa not contrarient, short counter septum, complex dissepimentarium) suggesting a distinct genus and possibly in another family. As discussed in Sorauf (1992), these "campophids" are somewhat older (lower Palmatolepis expansa Conodont Zone) than the classic European Strunian Campophyllum. In Europe, Campophyllum appears in the uppermost Famennian (base of Siphonodella praesulcata Conodont Zone) or a little earlier (P. expansa Conodont Zone; Berkowski 2002). From the beginning, Campophyllum shows a surprising morphological plasticity that can be explained by the quick recovery of numerous empty ecological niches after the demise of corals at the Frasnian–Famennian boundary and the very slow post-crisis diversification during the Famennian (Poty 1984, 2010; Berkowski 2002). Unpublished data of Edouard Poty (personal communication, May 2013) indicate the successive appearance of at least six yet unnamed species in a lineage characterized by an increase of corallium diameter and length of septa (Poty 1999). The final species are very large (30–50 mm), counting numerous long septa prefiguring the morphology of “Palaesmalia aquisgranensis” (Frech, 1885), that probably evolved from Campophyllum at the end of the uppermost Famennian (Poty 2010). Campophyllum and associated genera became extinct at the Hangenberg event preceding the D–C boundary (Poty 1999).

Campophyllum flexuosum (Goldfuss, 1826)

Fig. 5A–M.

1826 Cyathophyllum flexuosum sp. nov.; Goldfuss 1826: 47, pl. 17: 3a, b.
1850 Campophyllum flexuosum (Goldfuss); Milne-Edwards and Haime 1850: pl. 68.
1885 Cyathophyllum aquisgranensis sp. nov.; Frech 1885: 40, pl. 9: 1C.
1885 Cyathophyllum lindströmi sp. nov.; Frech 1885: 38.
1913 Caninia dordoloi sp. nov.; Salée 1913: 44: figs. 1, 2, pl. B: 2.
1917 Cyathophyllum aquisgranensis Frech; Vaughan 1917: 38, pl. 18: 3, 4.
1929 Cyathophyllum aquisgranensis Frech; Deheé 1929: 46, pl. 14: 3a, b.
1932 Caninia flexuosa (Goldfuss); Schindewolf 1932: 476, fig. 3.
1935 Caninia dordoloi Salée; Gorsky 1935: 104, pl. 8: 2, 3.
1961 Palaesmalia aquisgranensis Frech; Conil 1961: 348, pl. 18: 3, 4.
1965 Campophyllum flexuosum (Goldfuss); Hill and Jull 1965: 206, pl. 7.
1984 Campophyllum flexuosum (Goldfuss); Poty 1984: pl. 2: 1–3.

2005 Campophyllum flexuosum (Goldfuss); Chwieduk 2005: 411, pl. 1: 8, pl. 7: 1–3.
2010 Campophyllum flexuosum (Goldfuss); Poty 2010: 395, fig. 5.
2011 Campophyllum flexuosum (Goldfuss); Denayer et al. 2011: 160, pl. 1: B.
2013 Campophyllum sp. 2; Denayer 2013: 36, fig. 1E.

Type locality: Stoberg, near Aachen, Germany.
Type horizon: Strunian limestone “Zone d’Etroeungt”.

Material.—Thirty-six specimens and numerous fragments (65 TS, 20 LS); 24 from the Topluca (Bartın), 7 from Esenpinar (Bartın), and 5 from Gökgöl (Zonguldak), uppermost Famennian.

Diagnosis.—See Hill and Jull (1965).

Description.—The corallum is solitary and cylindrical, up to 15 cm high with a maximum diameter of 25 mm in the calyx. The external wall and parts of the dissepimentarium are often eroded in the large specimens. The mean tabularium diameter is 14 mm (maximum 21 mm). There are 45 septa in average (maximum 60; Fig. 6). The major septa are straight or slightly wavy in the dissepimentarium. They are usually long (up to 3/4 of the corallum diameter) but can be withdrawn or amplexoid in some cases (Fig. 5D, G). Despite their length, they do not reach the axis and leave a free zone of about 5 mm in diameter in the centre of the tabularium. The counter septum usually enters into this central zone. The cardinal septum is sometimes slightly shorter than its neighbours. The minor septa are long (1/2–3/4 of the length of the major septa) and sinuous, particularly in the dissepimentarium. They are contrarient or contralateral. Some of them are intercepted by second order londsdaleid dissepiments. The thickness of the septa is variable, even in one specimen. The thickening occurs mainly in the cardinal quadrants but the counter quadrants are also affected in some specimens. The cardinal fossula is variably marked. Alar fossulae occur occasionally in small sized sections (juvenile stages). The dissepimentarium counts 4–6 rows of concentric interseptal dissepiments (maximum 14 in large specimens). In the latter, the inner rows can be V-shaped and herringbone. The inner row is commonly thickened, particularly in the cardinal quadrants. Some incomplete rows of first and second order londsdaleid dissepiments are present in large specimens (Fig. 5M). The external wall is regular and thin. In longitudinal section, the tabulae are usually complete and regularly spaced (Fig. 5J, L). They are typically mesa-shaped, the central part being flat and rising 1–2 mm from the peripheral edge of tabulae. The dissepiments are narrow, often high and...
steeply inclined (70–80°) towards the tabularium. There are 10–12 tabulae and 10–15 dissepiments per centimetre in longitudinal section.

Remarks.—In addition to size variation, the variability is extreme in this species and affects all the skeletal elements. The length and thickness of septa can double, even in the same specimen. The cardinal fossula varies from a shallow depression occupied by a long cardinal septum, to an opened fossula edged by curved cardinal-lateral septa and occupied by short and thick septa, and to a long and narrow key-hole-shaped fossula incised in the dissepimentarium. The morphology of the juvenile stages varies from zaphrentoid pattern to amplexoid forms (Fig. 5D) or stages with radially disposed long septa (Fig. 5K). Also, the dissepimentarium varies from 0 to 20 rows of dissepiments—mainly interseptal but with common lonsdaleoid dissepiments of both orders in large specimens. This plasticity might indicate more than one species but no discrete character allows a clear separation between different forms, all being continuous and all the possible intermediate forms occur. Moreover the quantitative data (e.g., diameter versus number of septa; Fig. 6) form a single continuum. All of them are commonly observed in the toptotypic material of C. flexuosum (Edouard Poty, personal communication, May 2013). Further analysis based on the abundant French and Belgian material might refine the definition of C. flexuosum.

The specimens investigated here share with C. flexuosum (Goldfuss, 1826): (i) a long counter septum, (ii) sinuous (“flexuous”) septa, (iii) contratingent or contraclinant minor septa, (iv) a narrow dissepimentarium (comparatively to other species, see below). Chwieduk (2005) excluded from C. flexuosum corals with long and thick septa in the juvenile stages, a short cardinal and a long counter septum. However these morphological variations are common within C. flexuosum and do not justify a new species. C. flexuosum has dimensions similar to those of C. cylindricum Onoprienko, 1979b but the latter has straight septa and minor septa less contratingent.

Stratigraphic and geographic range.—Campophyllum flexuosum is common in the uppermost Famennian (Siphonodella praesulcata Conodont Zone) in the Namur-Dinant Basin, Aachen vicinity (Germany) and Avesnois (N France; Poty 1984), in Pomerania (Campophyllum sp. A; Chwieduk 2005) and possibly in the Holy Cross Mountains (juvenile stage named Campophyllum sp. figured by Berkowski 2002).

Campophyllum sp.

Fig. 5. Cyathophylline coral Campophyllum sp. from the uppermost Famennian (Strunian) of Bartın area, Topluca section, Turkey. A. ET.11.12.III, successive TS (A1, A2). B. ET.11.12.II, successive TS (B1, B2). C. ET.11.12, successive TS (C1, C2); close-up view of the dissepimentarium and cardinal fossula, TS (C1); L.S. (C3). D. ET.11.10, TS. Scale bar 5 mm for all specimens except C3, 3.75 mm.

Fig. 6. Scatter diagram showing the number of septa plotted against coralite diameter for Campophyllum flexuosum (Goldfuss, 1826) and Campophyllum sp.

Fig. 7. Cyathophylline coral Campophyllum sp. from the uppermost Famennian (Strunian) of Bartın area, Topluca section, Turkey. A. ET.11.12.III, successive TS (A1, A2). B. ET.11.12.II, successive TS (B1, B2). C. ET.11.12, successive TS (C1, C2); close-up view of the dissepimentarium and cardinal fossula, TS (C1); L.S. (C3). D. ET.11.10, TS. Scale bar 5 mm for all specimens except C3, 3.75 mm.
ous densely packed small tabellae. Their shape varies from horizontal, domed to mesa-shaped. Some are concave in the central part and show lateral shoulders (Fig. 7C4). In this case, small tabellae fill the concavity to make the tabularium flatter. The dissepiments are numerous and steeply inclined (70°–80°). Two morphologies occur in the same specimen: small globose dissepiments about 1 mm high and long and stretched dissepiments 1–1.5 mm high and 3–5 mm long. There are about 15 dissepiments and 30 tabulae (both complete and tabellae) per centimetre.

**Remarks.**—The large dimensions, the length of septa and the width of the dissepimentarium are the main characters distinguishing this species from *C. flexuosum* (Goldfuss, 1826). Nevertheless, the juvenile stages of both species are very similar: major septa thickened and flexuous, minor septa short, short counter septum (compare Fig. 5G and Fig. 7D). For a similar diameter, *Campophyllum sp.* usually shows a narrower dissepimentarium but this character rapidly changes during ontogeny. Detailed treatment of this form is pending and will be published elsewhere.

**Stratigraphic and geographic range.**—The species is known in Belgium (Edouard Poty, personal communication, May 2013) and Poland (*Campophyllum sp.* A of Berkowski 2002). In Turkey, *Campophyllum sp.* occurs in both Bartın and Zonguldak areas.

**Suborder Ketophyllina Zhavoronkova, 1972**

**Family Endophyllidae Torley, 1933**

**Genus Pseudoendophyllum Onoprienko, 1979b**

**Type species:** *Endophyllum nalivkini* Gorsky, 1935; uppermost Famennian of Novaya Zemlya, Russia.

**Diagnosis.**—See Berkowski (2002).

**Remarks.**—Onoprienko (1979b) created *Pseudoendophyllum* for the corals attributed to *Endophyllum* Torley, 1933 by Gorsky (1935, 1938) in the uppermost Famennian of Novaya Zemlya. As noticed by Berkowski (2002), Gorsky (1935) described his corals as *Endophyllum* because he could not highlight any difference with the Devonian genus. Nevertheless, no *Endophyllum* is known between the Frasnian and the uppermost Famennian, so the uppermost Famennian *Endophyllum* are possibly homeomorphs of the Middle Devonian ones and should thus be considered as Elvis taxa (Berkowski 2001). In Poland, Berkowski (2002) documented two species from the uppermost part of Middle Famennian (*Palmatoilepis marginifera* Zone) to uppermost Famennian (*Siphonodella praesulcata* Zone). The origin of the genus should consequently be situated, at least in the Early Famennian. Onoprienko’s (1979b) choice to create *Pseudoendophyllum* is justified if the Middle and Upper Devonian forms have a different origin. Berkowski (2002) proposes two hypotheses for this origin: (i) *Pseudoendophyllum* evolved from *Smithiphyllum* by acquiring a cerioid habit; (ii) *Pseudoendophyllum* is a *Tabulophyllum* that became colonial (this second option is also favoured by Jell and Hill 1970 for the origin of the Middle Devonian *Endophyllum*). *Tabulophyllum* being present in the Famennian (Poty 1984; Berkowski 2002), it might be at the origin of *Pseudoendophyllum*.

**Pseudoendophyllum sp.**

Fig. 5N–Q.

2013 cf. *Endophyllum sp.*; Denayer 2013: 36: 1D.

**Material.**—Fragments of two small colonies (5TS, 1 LS) from Dallica (Bartın), uppermost Famennian.

**Description.**—The colonies are small (10 cm in diameter), fasciculate to sub-cerioid (Fig. 5N). The corallites are cy-lindrical to sub-prismatic. Their mean width is 16 mm and their tabularium diameter is 9 mm in average (maximum 12 mm). There are 33 septa of each order (maximum 36). The major septa are long but do not reach the centre of the tabularium where a free zone of 1–3 mm large is usually present. They are sinuous or zig-zag, often thick at the base and sometimes up to the tabularium. The cardinal septum is short; the cardinal-lateral septa are also shorter and edge the opened cardinal fossula. The minor septa are long (more than half the length of the major) and enter into the tabularium. They are sinuous and thinner than the major. Some are contraclinal. In the outer part of the dissepimentarium, the major septa appear as septal crests on the wall or the lonsdaleoid dissepiments. All the septa are intercepted by first order (1–7 rows) and second order (3–5 rows) lonsdaleoid dissepiments. The interseptal dissepiments are concentric, V-shaped and herringbone. The wall is thin and regular but usually eroded. In longitudinal section, the tabulae are complete, mesa-shaped or domed, some are depressed axially (Fig. 5Q). The lonsdaleoid dissepiments are 1.5–3 mm long and 0.5 mm high. They are flat and gently inclined in the outer part of the dissepimentarium but smaller (1 mm) and more inclined (60–70°) near the tabularium. The inner row is vertical. There are 12–14 tabulae and up to 24 dissepiments per centimetre.

The increase is lateral and non-parricidal. The offsets appear in the peripheral part of the dissepimentarium. The smallest offsets observed are already cylindrical, 3–4 mm in diameter and have less than 20 short sinuous septa (Fig. 5P1). The lonsdaleoid dissepiments appear where corallites reach 4 mm in diameter. Unfortunately, the limited material prevents any blastogenic study of this species.

**Remarks.**—The Famennian species of *Pseudoendophyllum* described by Berkowski (2002) are cerioid but the Turkish colonies are fasciculate to sub-cerioid. Two hypotheses can explain this habitus. (i) The colonies are really fasciculate and the present specimen might deserve a distinct generic name. This view was supported by Berkowski (2002) in his review of the present genus as he pointed out the bilateral septal arrangement in some specimens. (ii) The fasciculate habit is due to an effect of sedimentation as documented in cerioid colonies of the genera *Lithostrotion*, *Hexagonaria* or *Phillipsastrea* (Scrutton 1998). This second hypothesis...
is supported by cauliflower-shaped stromatoporoid, occurring in the same horizon than *Pseudoendophyllum* colonies, both witnessing irregular or seasonal sedimentation. In that sense, the attribution of the Turkish specimens to *Pseudoendophyllum* is consequently acceptable.

*Pseudoendophyllum* sp. was collected in stromatoporoid beds in the Dallica section (Bartin). The foraminifer assemblage is poor but the occurrence of *Avesnella* indicates the lower part of the Strunian (DFZ5–6 biozones of Poty et al. 2006).

Subfamily Dibunophyllinae Wang, 1950

**Genus Bounophyllum** Chwieduk, 2005

*Type species:* *Clisiophyllum* (*Dibunophyllum*) *praecursor* Frech, 1885; Strunian of Stolberg (Aachen, Germany) = Bounophyllum pomeranicum Chwieduk, 2005; uppermost Famennian of Poland.


**Remarks.**—The genus *Bounophyllum* was introduced by Chwieduk (2005) for corals previously named *Dibunophyllum praecursor* (Frech, 1885). *Dibunophyllum* being a Viséan genus with well constrained characters, this name was not suitable for the uppermost Famennian specimens.

**Bounophyllum praecursor** (Frech, 1885)

Fig. 8H–L.

1885 *Clisiophyllum* (*Dibunophyllum*) *praecursor* sp. nov.; Frech 1885: 47, pl. 17: 3a, b.


2011 *Bounophyllum praecursor* Frech; Denayer et al. 2011: 164, pl. 1: G.

2013 *Clisiophyllum* cf. *omaliusi* Haime; Denayer 2013: 36: fig. 1: G.

**Type material:** Frech’s (1885) types were destroyed during Second World War. No neotype has been designated yet but numerous topotypes are known (e.g., collection PA.ULg, University of Liège, Belgium).

**Type locality:** Stolberg, near Aachen, Germany.

**Type horizon:** Strunian limestone “Zone d’Etroeuengt”.

**Material.**—Five specimens (16 TS, 2 LS), four come from Topluka (Bartin) and one from Gökgöl (Zonguldak), uppermost Famennian.

**Diagnosis.**—See Berkowski (2002).

**Description.**—The mean diameter of the corallum is 9.5 mm (maximum 11 mm) and the tabularium is 7 mm wide in average (maximum 9 mm). There are 30 septa of both orders (maximum 32). The major septa are long, straight in the tabularium and confluent with the columella. The minor septa are restricted to the dissepimentarium or enter shortly into the tabularium. The cardinal fossula is poorly developed. The axial structure is dibunophyllid or axophyllid, made of an axial plate with 25–30 twisted radial lamellae attached to the axial ends of the major septa. The largest axial structures are not necessarily developed in largest stages. The dissepimentarium counts no more than 2 rows of concentric interseptal dissepiments, several are thickened. The wall is regular. In longitudinal section, the tabulae are domed in the axial part of the tabularium and depressed in periphery. The dissepiments are steeply inclined toward the tabularium.

**Remarks.**—Chwieduk (2005) created the species *Bounophyllum pomeranicum* for specimens with dimensions and number of septa less than those of Frech’s (1885) species. However, these specimens fall in the variability of the topotypes of *B. praecursor* (Frech, 1885). *Bounophyllum pomeranicum* showing no other distinctive character, it is considered as a junior synonym of *B. praecursor*. The Turkish specimens fit in the same morphological field of variability, except for their axial structure showing an axial plate much more individualised than in topotypes. This type of variability is, however, commonly observed in taxa with a complex axial structure that may change during the ontogeny or from one specimen to another (e.g., *Clisiophyllum*, *Dibunophyllum*, *Axophyllum*).

**Stratigraphic and geographic range.**—*Bounophyllum praecursor* is common in the Strunian stromatoporoid biostromes and associated facies is Belgium, Germany (Poty 1984), and Poland (Chwieduk 2005). Its occurrence in Zonguldak and Bartin areas is the first record outside Europe.

Suborder Caniniina Wang, 1950

Family Cyathopsidae Dybowski, 1873

**Genus Uralinia** Stuckenberg, 1895

*Type species:* *Heliophyllum multiplex* Ludwig, 1862; Tournaissian of the Ural Mountains, Russia.

**Diagnosis.**—See Poty and Boland (1994).

**Uralinia simplex** (Yü, 1933)

Fig. 8F, G.

1933 *Pseudouralinia tangakuensis* var. *simplex*; Yü 1933: 60, pl. 5: 6.

1963 *Pseudouralinia tangakuensis simplex* Yü; Yü 1963: 144, pl. 35: 4.

1963 *Pseudouralinia simplex*; Fan 1963: 277, pl. 1: 5a–c.

**Holotype:** Specimen IPG-4938.

**Type locality:** Kolaho, Guizhou, SE China.

**Type horizon:** Lower Tournaissian Tangaku Formation.

**Diagnosis.**—See Yü (1933).

**Material.**—Nine specimens (12 TS, 2 LS) from Topluka (Bartin), lower Tournaissian.

**Description.**—The coralla are eroded and the thickened septa of the cardinal quadrants are usually the only pre-
served parts. The approximate diameter of the tabularium varies from 12 to 22 mm, depending on the erosion of peripheral parts. There are 28 septa in average (maximum 30). They are undulating, irregularly thickened but separated from each other, some interseptal dissepiments occupying the space between them. Their axial ends are sharp, except for the cardinal-lateral septa that develop rhopaloid ends. The cardinal septum is shorter and quite undulating. The
Cardinal fossula is poorly marked. Some interseptal and lonsdaleoid dissepiments are present in the counter side.

**Remarks.**—Uralinia simplex (Yü, 1933) is similar to *U. tangpakouensis* (Yü, 1931) by its irregular form, its sharp septa and its narrow lonsdaleoid dissepimentarium. It differs from the latter by lesser dimensions (12–20 mm versus 30–50 mm for *U. tangpakouensis*) and less septa (30 versus 30–50). Moreover, the septa are shorter and thicker in the cardinal quadrants in *U. simplex*.

**Stratigraphic and geographic range.**—In S China, *U. simplex* and *U. tangpakouensis* are the guide taxa for the lower Tournaisian *U. tangpakouensis* Zone of Tan et al. (1987), corresponding to the rugose coral RC17–RC2 subzones of Poty et al. (2006). In NW Turkey, the species occurs in the light bioclastic limestone of the lower Tournaisian part of the Yilanlı Formation in Bartın area. In equivalent levels of the Gökgöl section, only fragments of tabularium with thickened septa are questionably attributed to *U. simplex*. The foraminifers associated with the corals indicate the MFZ2 biozone of Poty et al. (2006).

**Family Bothrophyllidae Fomitschev, 1953**

**Genus Caninophyllum Lewis, 1929**

*Type species:* Cyathophyllum archiaci Milne-Edwards and Haimé, 1852; Viséan of England.

*Diagnosis.*—See Poty (1981).

*Remarks.*—Lewis (1929) created the genus *Caninophyllum* for caniniid corals with septa extending to the axis. This character allows the distinction with *Caninia* Michelin in Gervais, 1840, Siphonophyllia Scouler in McCoy, 1844 and Haplosoma Senenoff-Tian-Chansky, 1974 which all have withdrawn septa. The presence of a loose axial structure is one of the main differences with *Bothrophyllum* Trautschold, 1879. However, *Caninophyllum* shows sometimes such an axial structure made of the dilated ends of major septa (e.g., *Caninophyllum halkynense* Lewis, 1929). The evolution of the genus follows an increase of size and complexity. The stratigraphic succession of species in the Belgian Namur-Dinant Basin exemplified perfectly this lineage. *Caninophyllum patulum*, the oldest species in Belgium appears early in the Ivorian; *Caninophyllum* sp. A (Denayer et al. 2011: pl. 4J) characterized the upper Ivorian (Poty 1989); *Caninophyllum* sp. B (described as *C. patulum* by Poty 1981) occurs in the Moliniacian; *C. archiaci* is common in the Luvian then finally, *C. halkynense* appears in the Warnantian. This lineage possibly carries on in the Late Carboniferous where *Bothrophyllum* Trautschold, 1879 might have evolved from *Caninophyllum* with axial structure (Poty 1981).

**Caninophyllum charli** sp. nov.

*Fig. 8A–E.*

**Etymology:** In honour of François Charles, who first described corals in the Carboniferous of Zonguldak.

**Holotype:** Corallum included in a rock matrix, specimen G.8.1.1, Zonguldak 2011 (5 TS).

**Type locality:** Gökgöl section, south of Zonguldak, NW Turkey.

**Type horizon:** Yilanlı Formation, unit G8, lower Tournaisian (Hastarian, MFZ3 biozone of Poty et al. 2006).

**Material.**—Eighteen specimens (27 TS, 2 LS): 15, including the holotype, coming from Gökgöl (Zonguldak) and 3 from Dallica (Bartın), lower Tournaisian.

**Diagnosis.**—Small *Caninophyllum*, 30–32 mm in diameter (15–20 mm for the tabularium), having 42–46 septa of each order. Major septa extending to the axis in the juvenile stages but withdrawn in the mature stages, thickened in the cardinal parts of the tabularium. Minor septa rudimentary. Dissepimentarium narrow but complex, constituted of concentric, herringbone and arched interseptal dissepiments. Cardinal fossula conspicuous and opened.

**Description.**—The corallum is cylindrical, 3–5 cm high. The mean diameter is 32 mm (maximum 38 mm) and the tabularium is in average 17 mm wide (maximum 21 mm). There are, on average, 46 septa of each order (maximum 48). The major septa are long, reaching the axis in the juvenile stages but withdraw toward the periphery during the growth, leaving a central zone of 5–6 mm-wide in the centre of the tabularium (Fig. 8A2, C, D). They are thickened but their axial ends are sharp. They bend toward the cardinal fossula in the cardinal quadrants but are straighter in the counter quadrants. The initial thickening occurring in the whole tabularium rapidly decreases during the growth but maintains in the cardinal quadrants in the mature stages. The cardinal septum is shorter and thicker than its neighbouring septa. The minor septa are rudimentary or restricted to the peripheral part of the dissepimentarium. The cardinal fossula is well marked. The dissepimentarium counts 5–12 rows of concentric and herringbone dissepiments and several arched dissepiments in the peripheral part. Second order lonsdaleoid dissepiments occur in some specimens. The inner row of dissepiments is thickened in continuity with the septa (Fig. 8Aa). The wall is thin, regular or slightly undulating. In longitudinal section, the tabulae are incomplete, horizontal or domed in the axial part of the tabularium, domed or mesa-shaped in the peripheral part (Fig. 8E). A peripheral gutter develops in the mature stages. The dissepiments are 1.5–3 mm long, 1 mm high and steeply declined toward the tabularium.

*Remarks.*—The small size and number of septa are diagnostic of *Caninophyllum charli* sp. nov. and allow its discrimination from *C. archiaci* (Milne-Edwards and Haimé, 1852) and *C. tomiense* (Tolmachev, 1931). The new species shares its dimensions with *C. patulum* (Michelin, 1846) but the latter show a larger dissepimentarium usually composed only of concentric and herringbone dissepiments. The septa are less thickened and more withdrawn toward the periphery in *C. patulum* while its cardinal septum is longer in the juvenile stage. The tabularium is also different: the tabulae are flat or slightly domed in the central part in *C. charli*
but are clearly domed in *C. patulum*. Poty and Xu (1996) figured two species of small *Caninophyllum* from the lower Tournaian Uralinia tangakouensis Zone of S China. *C. cystosum* Jiang, 1982 has 41–46 septa for a diameter of 25–35 mm but differs from *C. charli* by an inconspicuous cardinal fossula and a long counter septum often connected to the cardinal septum. *C. shaoyangense* Jiang, 1982 is smaller (17 mm and 38 septa of both orders) and has a very large dissepimentarium and septa almost not thickened in the tabularium.

**Stratigraphic and geographic range.**—*Caninophyllum charli* sp. nov. was collected in a biologic level dated of the lower Tournaian (Hastarian) by foraminifers (MFZ3 biozone) in the Gökgöl (Zonguldak). Crushed specimens were collected in equivalent levels in the Dallula (Bartın).

**Suborder Metriophyllina Spassky, 1965**

**Family Lacophyllidae Grabau, 1928**

**Genus Amplexochalinia** Soshkina, 1928

*Type species:* Amplexochalinia muralis Soshkina, 1928; Upper Permian of Ural Mountains.


**Remarks.**—The oldest species attributed to the genus *Amplexochalinia* is Middle Devonian (Rózkowska, 1969; Lütte and Galle 1989) but the genus is particularly common in the Carboniferous (see De Groot 1963). Studies of its ontogeny showed that the genus is probably polyphyletic (Fedorowski 1986; Moore and Jeffords 1986).

**Amplexochalinia rozkowskae** Fedorowski, 2003

Fig. 8H.

1969 Amplexochalinia muralis Soshkina; Rózkowska 1969: 82, pl. 3: 5, 8, 9, pl. 8: 6.


2005 *Amplexochalinia rozkowskae* Fedorowski; Chwieduk 2005: 408, pl. 5: 5.

2009 *Amplexochalinia rozkowskae* Fedorowski; Fedorowski 2009: 237, fig. 3E, F.

*Holotype:* Specimen 3/25a figured as *Amplexochalinia muralis* by Rózkowska (1969: pl. 3: 5a, b).

*Type locality:* Kadzielnia, Holy Cross Mountains, S Poland.

*Type horizon:* Famennian, Upper Devonian.

**Material.**—Single specimen (1 TS) from the Dallula (Bartın), uppermost Famennian.

**Diagnosis.**—See Fedorowski (2003).

**Description.**—The corallum is 2 mm in diameter, its aulos is well developed and 0.75 mm in diameter. There are 9 septa, thickened at the base, thin elsewhere. The minor septa are not developed. The cardinal fossula is marked by a slight withdrawal of the aulos edge toward the periphery. There are no dissepiments. The wall is 0.3 mm-thick and regular.

**Remarks.**—The diameter and number of septa are compatible with these of *Amplexochalinia rozkowskae* Fedorowski 2003, particularly if considered as a juvenile specimen like those figured by Chwieduk (2005). *A. rozkowskae* Fedorowski 2003 is the sole species of *Amplexochalinia* Soshkina, 1928 described in the Famennian. The other aulos-bearing genera known in equivalent strata are *Syringaxon* Lindström, 1882 (Chwieduk 2005) and *Neaxon* Kullmann, 1965 (Semenoff-Tian-Chansky 1988; Berkowski 2002). Both have a narrow aulos and thickened septa and wall.

**Stratigraphic and geographic range.**—*Amplexochalinia rozkowskae* occurs in the Famennian of Pomerania (Chwieduk 2005). The present specimen was collected, together with *Pseudoendophyllum* sp., in the Yilanli Formation in the Dallula (Bartın). The occurrence of the foraminifer *Avesnella* sp. indicates the lower part of the Strunian DFZ5–6 biozones of Poty et al. (2006).

**Family Metriophyllidae Hill, 1939**

**Genus Metriophyllum Milne-Edwards and Haime, 1850**

*Type species:* Metriophyllum bouchardi Milne-Edwards and Haime, 1850.

?*Metriophyllum* sp.

Fig. 8I.

**Material.**—Single specimen from the stromatoporoid biostromes of Topluka (Bartın), uppermost Famennian.

**Description.**—The section has a diameter of 3 mm and there are 16 septa. The latter are thin and fuse together at the centre of the corallum. No septal spine was observed. There is neither fossula nor dissepiments. The wall is thin.

**Remarks.**—Small solitary undisseminated and columnate rugose corals occur in the Strunian of Germany and Belgium and in equivalent levels in N Poland. They were never described or classified in an accurate way. Chwieduk (2005) classified his specimen as *Lophophyllum* sp.; Bless et al. (1998) attributed the corals from W Germany to ?*Metriophyllum* sp. while Denayer et al. (2011) named the corals from Belgium *Amygdalophyllum*? sp. This taxon seems to be restricted to stromatoporoid facies of the uppermost Famennian. This specimen is similar to the juvenile stages of corals attributed to ?*Amygdalophyllum* or ?*Metriophyllum* from Belgium and Germany. These taxa are also similar to juvenile stages of the coral figured by Rózkowska (1969) under the name *Fasciculophyllum dobrojubovae* from equivalent levels of the Holy Cross Mountains (S Poland).

**Distribution of corals across D–C boundary**

The Strunian (uppermost Famennian) assemblage of NW Turkey is not particularly diversified (in comparison with those of Belgium and Poland), but two successive assem-
blages can be recognized. Two assemblages are also known in the Hastarian (lower Tournaisian).

_Pseudoendophyllum assemblage._—_Pseudoendophyllum_ sp. and _Amplexocarinia rozkoskewae_ are the only rugose corals observed in the Dallia section. Both are known in S Poland (Berkowski 2002) in level attributed to the “Upper Famennian” (i.e., Upper to uppermost Famennian _Sphaenosipira_ Brachiopod Zone of Balifski 1995). _Pseudoendophyllum_ is also known in similar deposits of Novaya Zemlya (Gorsky 1935, 1938). The genus is unknown in Western Europe except for one colony from the Upper Famennian of Aachen area, cited but not figured by Wulff (1922) and destroyed during the war. Poty et al. (2006) did not used _Pseudoendophyllum_ in their biostratigraphic chart but this assemblage can confidently be correlated with the RCo0 of these authors. The foraminifer genus _Avesnella_ (diagnostic for the lower Strunian DFZ5–6 biozones of Poty et al. 2006) was identified in the _Pseudoendophyllum_ horizon in Turkey.

_Campophyllum assemblage._—This assemblage is dominated by _Campophyllum flexuosum_ and _Campophyllum_ sp. These two species occur mainly in bioclastic facies while the solitary _Bounophyllum praecursor_ and _Metriophyllum_ sp. are restricted to the stromatoporoid reefal facies. In the Topluca section, the last _Campophyllum_ occurs c. 25 m below the first Tournaisian corals and the interval between the two occurrences is devoid of macrofauna. Nevertheless, the foraminifers are abundant and the DFZ7 biozone is easily identified up to the D–C boundary. The _Campophyllum_ assemblage can be correlated with the correlated with the rugose coral RC0f subzone of Poty et al. (2006), i.e., the upper part of the Strunian.

_Uralinia simplex assemblage._—The first Tournaisian coral occurs in the limestone and dolostone overlying the D–C boundary. The first occurrence of _Uralinia simplex_ in the Topluca section is 6 m above the boundary (based on the last occurrence of the foraminifer _Quasiendothyra kobeitusana_, DFZ7, and the first unilocular foraminifers, MFZ1). In the Topluca section, _Uralinia simplex_ is common in the lower part of the lower Tournaisian and the highest specimen was collected about 40 m above the base of the stage. _Uralinia simplex_ is the dominant taxon of the assemblage and only one fragment of unidentified zaphrentoid undissepimented rugose coral was noticed. This _Uralinia simplex_ assemblage is correlated with the _Uralinia tangpakouensis_ Zone of Tan et al. (1987) and the rugose coral RC1y subzone of Poty et al. (2006).

_Caninophyllum charli horizon._—In Gökgöl, the lower Tournaisian is relatively poor and only _Caninophyllum charli_ was recognized with some confidence from a single horizon. Crushed specimens were recovered in the Dallia section of the Bartın area. This occurrence is interesting since in Western Europe, the genus appears in the uppermost Hastarian (Poty 1989; Poty et al. 2006) in the MFZ4 biozone (lower part of Yvoir Formation and equivalents) but seems to appear earlier in Turkey (MFZ3). In Southern China, the genus also appears earlier, in the _Uralinia tangpakouensis_ Zone (Poty and Xu 1996).

**Summary.**—In NW Turkey, the rugose corals do not allow a precise stratigraphy at the D–C boundary due to a lack of material in the critical interval. Nevertheless, the four assemblages recognized on each side of the boundary are useful locally to estimate the position of the boundary and widely, to establish the correlation with Western Europe, Eastern Europe, and Chinese areas. The D–C boundary was identified by the foraminiferal succession (quasiendothyrids, unilocular, tournayellids) but the value of these markers is under discussion as _Quasiendothyra_ was documented in the Lower Carboniferous (Kalvoda and Kukal 1987; Kalvoda et al. 2015). The Hangenberg event was not recognized in the Turkish localities from a lithological point of view (no obvious facies or colour change, no black shale) and no geochemical data are available for the investigated sections. The extinction event associated with the Hangenberg is marked by the last occurrences of _Campophyllum flexuosum_ and _Campophyllum_ sp. in the Topluca section, about 19 m below the D–C boundary based on the foraminifers. The distribution of the foraminifers is still in a preliminary stage and no data on conodonts are available. The first Carboniferous coral (small _Uralinia_ and _Caninophyllum_) appear 6 m above the D–C boundary.

**Palaeogeographic affinity**

Uppermost Famennian (Strunian) rugose corals are not rare and usually thought to form endemic assemblages (Poty 1986, 1999) but actually, some taxa are more widely distributed than previously concluded. For example, the shallow water assemblages of Western Europe (Belgium, N France, W Germany) contain only solitary rugose corals while the Polish (Kraków area), Uralian (including Novaya Zemlya) and Siberian (Omolon Massif) assemblages contain solitary and a couple of colonial genera (Gorsky 1935, 1938; Conil et al. 1982; Poty and Onoprienko 1984) and the coral faunas from South China contain many colonial and solitary genera (Wu et al. 1981; Poty and Xu 1996, 1997). Some assemblages dominated by undisepimented rugose corals are also known (Montagne Noire in S France, Semenoff-Tian-Chansky 1988; Moroccan Anti-Atlas, Weyer 2002; German Thuringia and Rheinish massifs, Weyer 1971, 1989; Korn and Weyer 2003; Holy Cross Mountains in S Poland, Różkowska 1969) but are clearly facies-related “_Cyathaxonia_ fauna”. The NW Turkey area provides an interesting point of view as it was situated in a transitional biogeographic area during the considered time slice. The Istanbul-Zonguldak Zone was part of the southern margin of Baltica, facing the
Palaeotethys Ocean southward and surrounded north-, east- and west-ward by a carbonate shelf (Golonka 2007; Fig. 9).

The compilations of data available in literature led to the building of a database of rugose coral genera occurrences in the uppermost Famennian. A cluster analysis was conducted on this presence/absence database (see SOM: table 1, Supplementary Online Material available at http://app.pan.pl/SOM/app61-Denayer_SOM.pdf) using the paired Simpson coefficient and a bootstrap replicates value of 10,000. The resulting cluster (Fig. 10) shows three clusters: one containing only the New Mexico assemblage (Sorauf 1992) which is based on the single Percha Shale Fauna and is not very well constrained stratigraphically (lower Palmatelepis expansa Conodont Zone, i.e., Upper Famennian; Sorauf 1992). This N American Province forms an outgroup to all the other faunas. A second cluster unites Asian localities (Armenia, S China, Vietnam, Tibet, and NW Australia) and corresponds to an Asian Palaeotethyan Province (Asian margin of Gondwana). The third clade groups all the other localities. In the latter, one sub-cluster is clearly separated and include the shallow-water assemblages of the European Palaeotethyan Province while the three localities characterized by their “Cyathaxonia fauna” of deeper facies are grouped in two branches. The Namur-Dinant Basin (Belgium, N France, W Germany), Sudetes and Kraków area (S Poland), Pomerania-Rügen area (NW Poland and NE Germany) co-occur in this cluster, together with Novaya Zemlya, the Siberian Omolon Massif, and NW Turkey. The Western and Eastern Europe Provinces of Dubatolov and Vassiljuk (1980), Fedorowski (1981), and Sando (1990) are not clearly separated in the cluster but the distribution of the taxa shows clearly two major provinces: the European Palaeotethyan Province (“Campophyllum fauna”; Figs. 9, 10) in which most shallow-water carbonate localities are characterised by the genus Campophyllum; and the Asian Paleotethyan Province (“Cystophrentis fauna”; S China, Tibet, NW Australia, Vietnam, Armenia), where the genus Cystophrentis is diagnostic. The Istanbul Zone of NW Turkey belongs to the European Palaeotethyan Province and shares the genera Campophyllum, Metriophyllum, and Boumophyllum with the Namur-Dinant Basin and Pomerania-Rügen (both in the Western Europe Province of Dubatolov and Vassiljuk 1980; Fedorowski 1981; Sando 1990); and the genera Ampelocarina and Pseudoendophyllum with the Sudetes, the Ural Mountains, and Novaya Zemlya (eastern part of Laurussia, Eastern Europe Province of Dubatolov and Vassiljuk 1980; Fedorowski 1981; Sando 1990). A “mixed” influence is noticed and may result of an overlapping of the two palaebiogeographic provinces or from convergent dispersal paths in link with oceanic currents. Unfortunately, the poor stratigraphic resolution and the lack of any palaeoceanographic model prevent any precise reconstruction. This similarity may also be due to a geographic closeness of the Istanbul Zone to the considered areas (S Poland, Ural Mountains) situated on the margin of Laurussia at this time. Tari et al. (2012) suggest a closer
Conclusions

The uppermost Famennian (Strunian) coral assemblages of Barton and Zonguldak is dominated by the solitary genera *Campophyllum* and *Bounophyllum*, associated with the colonial genus *Pseudoendophyllum* and the undisseminated genera *Amplexocarinia* and *?Metriophyllum*. The occurrence of the first two genera indicates a similarity of NW Turkey with the Namur-Dinant Basin (Belgium, N France, W Germany) and Pomerania-Rügen (NW Germany, NE Poland) while *Pseudoendophyllum* indicates an affinity with the Sudetes (S Poland), Novaya Zemlya and the Ural Mountains. All these taxa disappear before the D–C boundary as an effect of the Late Devonian Hangenberg event, while the first Carboniferous coral appear 6 m above the boundary. Nevertheless, the classic facies associated with this global event (black shale) are lacking in the investigated sections in NW Turkey. This can be explained by the shallow-water settings of the studied areas. The proximal position prevented the shelf being reached by the transgressive euxinic water body. Similar situations were documented from other shallow-water sections (e.g., classical sections in the Namur-Dinant Basin, Azmy et al. 2009; Trolp section in the Graz Palaeozoic, Kaiser et al. 2008; Lesnilom section in the Moravian Karst, Kumpan et al. 2014).

Acknowledgements

The author thanks Tezcan Cobanoğlu for his help in the field in the Barton area in 2010–2011. Fieldwork and research were supported by a FRIA grant from the Belgian Fond National de la Recherche Scientifique (FNRS) and the Service de Paléontologie animale et humaine (University of Liège, Belgium). Luc Hance (Carmeuse s.a., Belgium) is thanked for his help on the determination of foraminifers and stratigraphy. The author is deeply indebted to Markus Aretz (University of Toulouse, France) and Edouard Poty (University of Liège, Belgium) is thanked for fruitful discussions on taxonomy and stratigraphy. Błażej Berkowski (A. Mickiewicz University, Poznań, Poland), Andreas May (Saint Louis University, Madrid, Spain), Ross McLean (Anadarko Co, Calgary, Canada), and Gregorz Racki (University of Silesia, Katowice, Poland), are acknowledged for their constructive reviews and comments of the manuscript.

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DENAYER—RUGOSE CORALS ACROSS D–C BOUNDARY


