

Taxonomy, Biostratigraphy and Palaeobiogeography of the Late Tournaisian rugose corals of north-western Turkey

Julien Denayer

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Abstract This article provides the first taxonomic description of Ivorian (Late Tournaisian, Early Carboniferous) rugose coral associations from north-western Turkey (Zonguldak and Bartın). Eleven species belonging to ten genera are described, one species is new. Three biostratigraphic assemblages are recognized. The oldest assemblage includes *Cyathaxonia cornu*, *Cyathoclisia uralensis*, ‘*Lophophyllum*’ *konincki* and *Uralinia multiplex*. This corresponds to the RC3 Biozone (early Ivorian). The middle assemblage is characterised by *Amplexus coralloides*, *Sychnoelasma hawbankense* and *Zaphriphyllum daleki* sp. nov. and is correlated with the early late Ivorian RC4 α Biozone. The youngest assemblage (RC4 β 1 Biozone, latest Ivorian) is composed of *Corphalia fourmarieri*, *Corphalia* sp. and *Amygdalophyllum?* sp. These three assemblages have a low specific and generic diversity compared to time-equivalent assemblages but contain genera with a wide distribution in the Palaeotethys Ocean, such as *Cyathoclisia*, *Uralinia* and—in a lesser extend—*Zaphriphyllum*, as well as typically European taxa such as *Corphalia* and *Sychnoelasma*. These latter two, identified for the first time outside of Europe, allow associating north-western Turkey with the European Coral Province.

Keywords Corals · Carboniferous · Tournaisian · Ivorian · palaeogeography · stratigraphy

Kurzfassung Diese Arbeit präsentiert die ersten taxonomischen Beschreibungen von Assoziationen rugoser Korallen aus dem Ivorium (spätes Tournais, Unterkarbon) aus dem Nordwesten der Türkei (Zonguldak und Bartın). Es werden insgesamt elf Arten in zehn Gattungen beschrieben; eine der Arten ist neu. Drei biostratigraphische Assoziationen werden unterschieden. Die älteste beinhaltet die Arten *Cyathaxonia cornu*, *Cyathoclisia uralensis*, ‘*Lophophyllum*’ *konincki* und *Uralinia multiplex*. Dies entspricht der RC3 Biozone (frühes Ivorium). Die mittlere Assoziation wird durch *Amplexus coralloides*, *Sychnoelasma hawbankense* und *Zaphriphyllum daleki* sp. nov. Charakterisiert und wird mit der früh-spätivorischen RC4 α Biozone korreliert. Die jüngste Vergesellschaftung (RC4 β 1 Biozone, spätestes Ivorium) beinhaltet die Taxa *Corphalia fourmarieri*, *Corphalia* sp. und *Amygdalophyllum?* sp. Diese drei Assoziationen haben eine niedrige Arten- und Gattungen-Diversität, im Vergleich mit anderen, gleichalten Vergesellschaftungen, aber beinhalten Gattungen, die zu jener Zeit eine weite Verbreitung in der Paläotethys hatte, wie etwa *Cyathoclisia*, *Uralinia* und - in geringerem Maße - *Zaphriphyllum*. Daneben kommen typische europäische Taxa vor, wie *Corphalia* und *Sychnoelasma*. Diese beiden Gattungen, die hier zum ersten Mal außerhalb Europas identifiziert werden, erlauben es, das Ivorium der nordwestlichen Türkei mit der europäischen Korallen-Provinz zu assoziieren.

J. Denayer (✉)

Service de Paléontologie animale et humaine, Département de Géologie, Université de Liège, Bat. B18, Allée du Six-Août Sart Tilman, B-4000 Liège, Belgium
e-mail: julien.denayer@ulg.ac.be

Present Address:

J. Denayer
School of Earth Sciences, Integrated Palaeoenvironmental Research Group, University of Queensland, St-Lucia, QLD 4072, Australia

Schlagwörter Korallen · Karbon · Tournaisium · Ivorium · Paläogeographie · Stratigraphie

Introduction

The Lower Carboniferous of north-western Turkey is poorly known. Studies on regional geology (Ralli 1895; Tokay 1954; Charles 1931, 1933) documented various carbonated facies of Tournaisian and Viséan age. The rugose corals were first noticed by Ralli (1895) in the Late Viséan of the Bartın area, then Charles (1933) described material from the Zonguldak area. While the Viséan corals were documented by Charles (1933), Ünsalaner-Kiragli (1958), Dîl et al. (1976), the Tournaisian corals were completely unknown. Dîl (1975, 1976) provided the first stratigraphic scheme for the Late Devonian—Late Viséan succession of the Zonguldak area and recognized the Tournaisian (Early Tournaisian ‘Tn1b-Tn2’ to Late Tournaisian ‘Tn3’). Our recent re-investigation of Charles’s and Dîl’s localities provided a diversified rugose coral fauna ranging from the Hastarian to the Latest Viséan. These associations allow a comparison with the well-known faunas of Eurasia. This paper is part of a larger study undertaken to test the palaeobiogeography of north-western Turkey during the Early Carboniferous. The present paper aims to describe the rugose corals collected in the Ivorian (Late Tournaisian) from the Zonguldak and Bartın area, to discuss their stratigraphy and their utility in palaeobiogeography.

Geographical and geological settings

The Istanbul-Zonguldak Zone is classically divided into the Istanbul and Zonguldak areas (or terranes). In the Istanbul Zone (West), the Early Carboniferous is represented by a thick radiolarite-flysch series (Baltalmanı and Trakya formations, see Özgül 2012 and references within). In the Zonguldak Zone (East, Zonguldak and Bartın areas, Fig. 1), the Yılanlı Formation includes all the carbonate rocks of Late Devonian to Late Viséan age. A detailed lithostratigraphy of the Tournaisian and Viséan is not available but many lithological units were identified in the studied sections (Fig. 2).

The Gökgöl section is situated along the road D750 Devrek-Zonguldak, upstream of the Asma hamlet, 4 km south of Zonguldak town (41°26′19.28″N–31°50′05.43″E, G in Fig. 1c). The Strunian and Hastarian strata are exposed south of the road tunnel. The Ivorian to Viséan units crop out north of the tunnel (Dîl 1975; Denayer 2011). Lithological unit G10 (Fig. 2) follows a thick package of mainly dark and fine-grained limestone (G9). It is composed of 15 m of light grey wackestone and packstone with numerous ostracods, passing upward to mudstone with birds-eyes. This unit is capped by an erosive surface. No fauna allows dating this unit. The next units are composed of bedded dark packstone (G11) overlain by

20 m of coarse-grained limestone (G12) capped by a pedogenic clayish bed (possibly a weathered tonstein). The unit G13 has three subdivisions. The lower part (G13a) is a thick package of well bedded limestone with cherts and some brachiopods shells. A massive grainstone-rudstone bed with abundant brachiopods, gastropods and syringopods constitutes the G13b sub-unit whereas the G13c sub-unit shows a similar facies enriched by numerous oncoids formed around small *Corphalia fourmarieri*. The *Corphalia fourmarieri* beds are presumably the type-horizon of the species collected and described by Charles (1933). An erosive surface, upon which rests the first Moliniacian deposits, caps this last unit.

The Kokaksu section is situated in the Kokaksu creek valley near the Çaydamar hamlet 2 km south of Zonguldak (41°25′59.72″N 31°48′25.40″E, K in Fig. 1c). The Ivorian is exposed in a disused quarry and along the creek 120 m downstream. It is dominated by massive light grey limestone (bioclastic packstone-grainstone) but is poorly fossiliferous: some brachiopods, bryozoans and small *Caninia* sp. were collected in the lithological unit K2 (Fig. 2). The unit KR3 is richer in fossils (including numerous *Corphalia fourmarieri*) and is dominated by well-bedded oncoidic packstone with cherts. The fossils are often silicified in this section (Denayer 2011).

The Topluca section is situated 7 km northwest of Bartın town, along a track between the Topluca earth pit and the valley road (41°41′15.15″N–32°16′99.70″E, T in Fig. 1d). The section exposes discontinuously the Strunian to Viséan strata (mainly Warnantian, Denayer, [in press b](#)). The Ivorian is poorly exposed and is separated from the last Hastarian beds by a hiatus about 25 m thick. Lithological unit ET9c is a marker bed in the whole Bartın area, consisting of massive light grey grainstone-rudstone with numerous brachiopod shells. This level yielded only the solitary rugose coral *Corphalia* sp. and micheliinid tabulate corals. The foraminiferal assemblage indicates the MFZ7 or MFZ8 Biozones of Poty et al. (2006), i.e. the upper part of the Ivorian. The following unit ET8c is partly covered and yielded no fauna. The next unit (ET8b) is similar but more massive and slightly dolomitized. It yielded a single specimen provisionally attributed to *Amygdalophyllum* sp. (not described here). An observational gap separates this last unit from the Moliniacian strata.

The Pelenkoğlu quarry is situated along the road joining the Esenpınar village to the Bartın valley, 9 km north-west of Bartın (41°41′35.41″N 32°15′32.44″E, P on Fig. 1d). The Ivorian is exposed in the center of an anticline. The lowest unit (P1) is made of well-bedded finely bioclastic packstone-grainstone with small cherts. Only *Cyathaxonia cornu* was found in this level. Unit P2 is a 10 m-thick unit of massive light grey bioclastic grainstone, overlain by a 15 m-thick unit (P3) of bedded mudstone-wackestone with

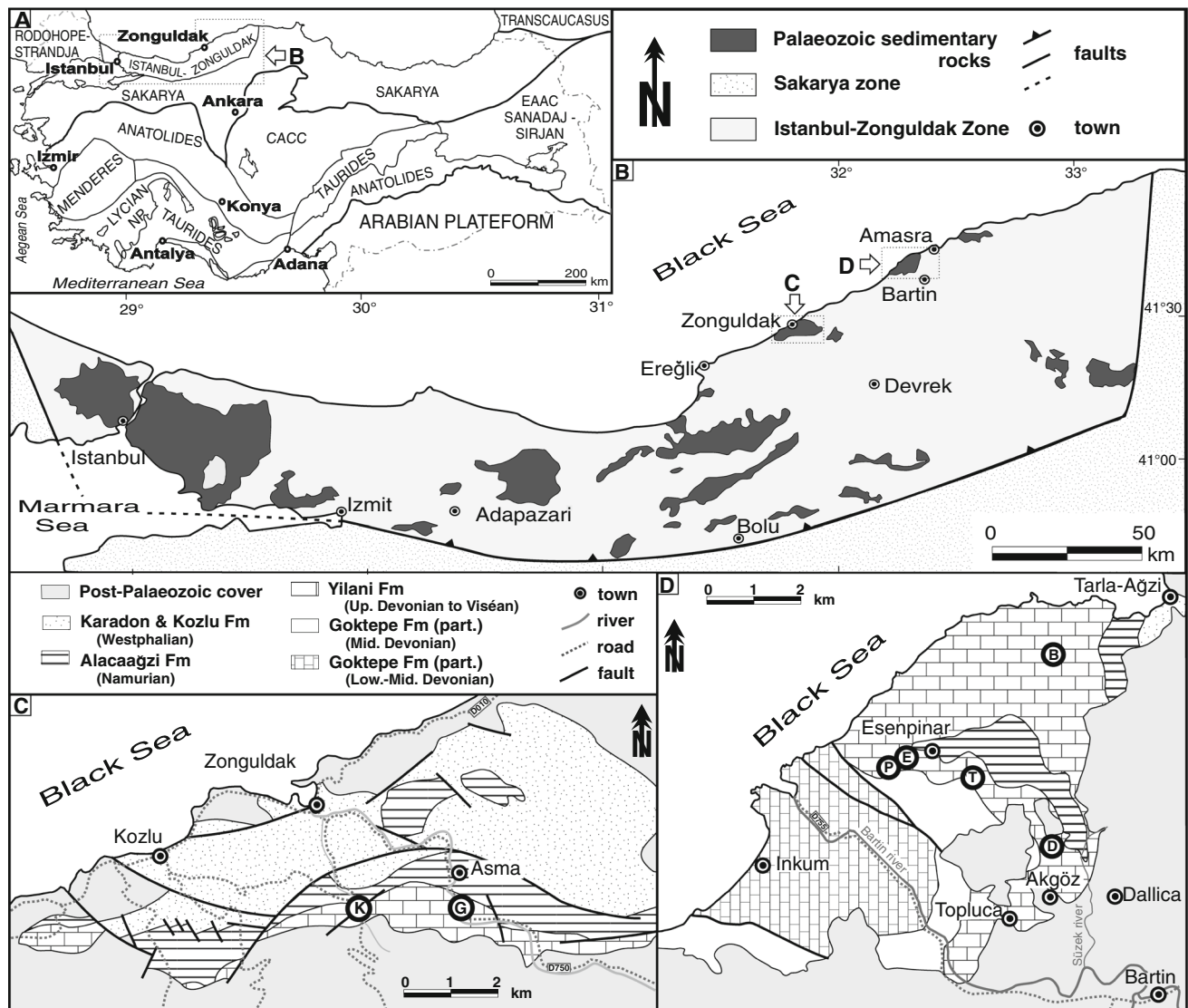


Fig. 1 **a** General structural map of Turkey (modified after Görür and Tüysüz 2001; Moix et al. 2008 and Okay 2008). **b** Geological map of the Istanbul-Zonguldak Zone (modified after Okay et al. 2006) with the position of the Zonguldak and Bartın areas. **c** Simplified geological map of the Zonguldak area (redrawn after Hoşgörmez 2007 and Charles 1933) with the location of the sampled sections (G Gököl section, K Kokaksu section). **d** Simplified geological map

of the Bartın area (redrawn after Tokay 1954) with the location of the sampled sections (B Tarla-Ağzı section, D Dallica section, E Esenpınar section, P Pelenkoğlu quarry, T Topluca section). Abbreviations: CCAC Central anatolian crystalline complex, EAAC East anatolian accretionary complex (Sanadaj-Sirjan Block), Lycian Np. Lycian nappes

some bioclastic horizons. One of these horizons yielded *Uralinia multiplex*, *Cyathoclisia uralensis* and '*Lophophyllum konincki*', as well as foraminifers indicating the MFZ5 Biozone (Fig. 2). The unit P4 is a marker bed correlated with an identical horizon with small *Uralinia* in the Esenpınar and Dallica sections (see below).

The Dallica section is composed of a series of small outcrops along a forestry path north of the Akgöz hamlet (41°40'05.50"N–32°18'36.58"E, D on Fig. 1d). One outcrop of massive light grey grainstone with brachiopods and

corals yielded numerous fragmented specimens of *Uralinia multiplex* as well as syringoporids.

The Esenpınar section is a succession of small outcrops situated along the road from Esenpınar to Bartın. *Uralinia multiplex* and *Sychnoelasma hawbankense* were collected from two limited outcrops approximately 1 km west of the hamlet (41°41'42.90"N–32°15'50.64"E, E on Fig. 1d). The first outcrop can be correlated with similar levels in the Pelenkoğlu quarry and Dallica sections but the second outcrop is not positioned precisely in the stratigraphic

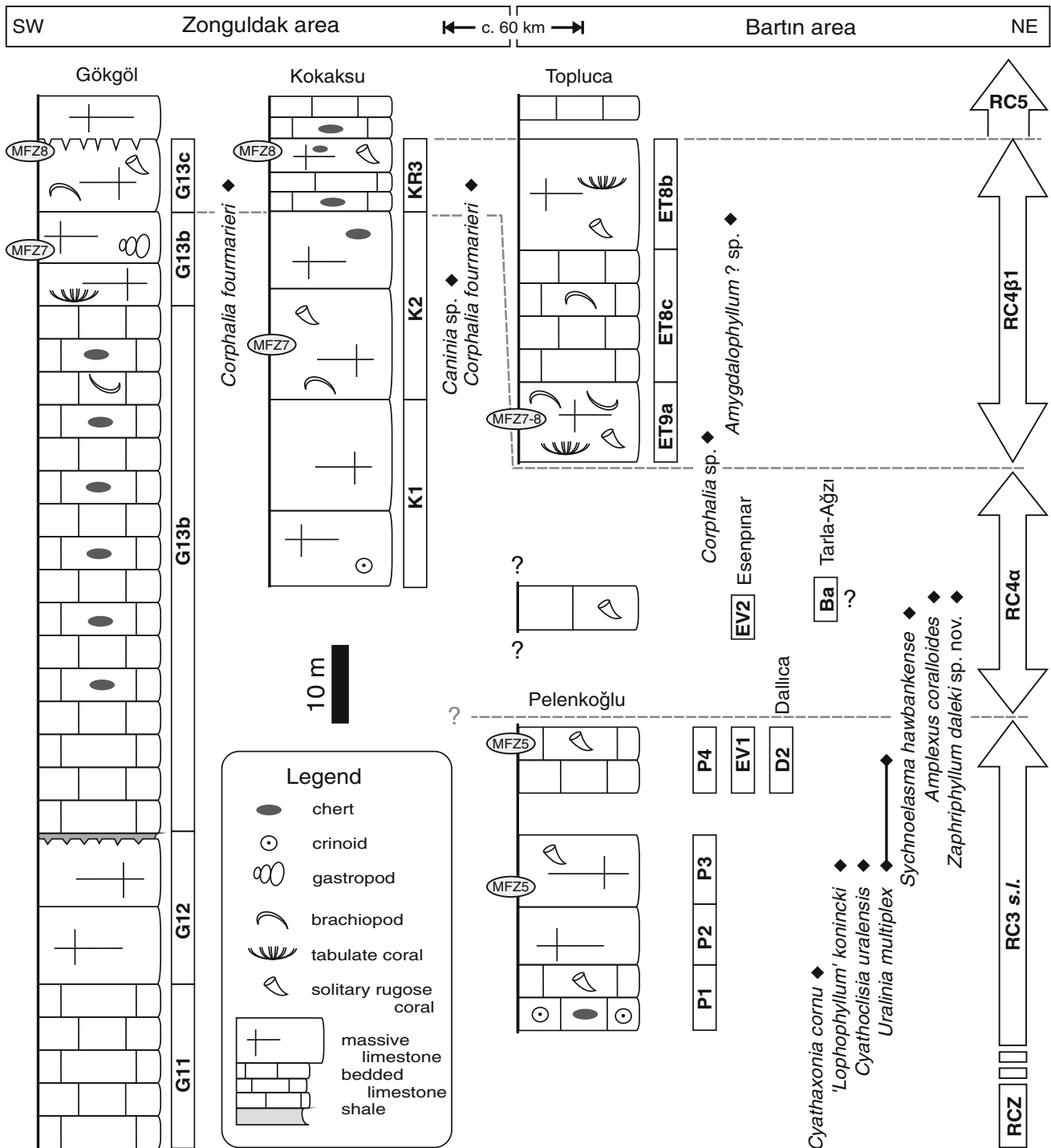


Fig. 2 Lithologic columns of the Yılanlı Formation in the studied sections. The *alpha-numeric* symbols (*G13c*, *K2*, *P3*, *ET9c*, *D2*, *EV3*, *Ba*, etc.) designate the lithological units described in the main text. The stratigraphic position of the coral species are indicated in parallel to the sections, except for *Uralinia multiplex* which occurs in the *P4*,

EV1 and *D2* units in the Pelenkoğlu, Esenpinar and Dallica section, respectively. *RCZ*: rugose coral biozones of Poty et al. (2006); *MFZ* (in gray ellipses): foraminiferal biozones of Poty et al. (2006) indicated only for samples confidently identified. The stratigraphy is discussed in the main text

succession. It rests upon the *Uralinia* beds but below the Viséan and thus considered as Ivorian.

The Tarla-Ağzı outcrop is situated along a forestry path (41°42'03.69"N 32°19'39.65"E, B on Fig. 1d). The corals

(*Amplexus coralloides* and *Zaphriphyllum daleki* sp. nov.) collected there are from an horizon not dated by biostratigraphy because no guide taxa (neither coral nor foraminifer) was identified. Nevertheless, the facies (pelloidal

wackestone and mudstone) recalls those observed in the Topluca and Esenpinar sections in horizons dated of the Ivorian.

Systematic palaeontology

The specimens were collected between 2008 and 2011 in seven sections in the Bartın and Zonguldak areas. The study is based on 84 specimens (c. 120 thin sections), including the type specimen of *Corphalia fourmarieri* of Charles collection stored in the Belgian Institute of Natural Sciences (number IP-10861-11). Newly collected specimens were deposited in the collections of Animal and Human Palaeontology of the University of Liège (Belgium) under the label ULg.PA. Abbreviations: Ba: Tarla-Ağzı outcrop, EV: Esenpinar section, ET: Topluca section, G: Gökgöl section, K and KR: Kokaksu section, P: Pelenkoğlu quarry. The classification follows Hill (1981) unless specified. Terminology is that of Hill (1981), updated by that of Scrutton (1998) and Fedorowski et al. (2007)

Phylum Coelenterata Frey and Leuckart 1847

Subphylum Cnidaria Hatschek 1888

Class Anthozoa Ehrenberg 1834

Subclass Rugosa Milne-Edwards and Haime 1850

Family Zaphrentoididae Schindewolf 1938

Genus *Sychnoelasma* Lang et al. 1940

Type species: *Verneulia urbanowitschi* Stuckenberg 1895, Lower Carboniferous of the Ural Mountains.

Diagnosis: See Cotton (1973).

Sychnoelasma hawbankense Mitchell and Somerville 1988 (Fig. 3a)

1908 *Zaphrentis konincki* mut. C2 Vaughan.—Carruthers: 70.

1915 *Zaphrentis konincki* Vaughan: 17.

1938 *Zaphrentis konincki* var. *magna* Gorsky: 19, pl. 2, Fig. 3.

1940 *Sychnoelasma urbanowitschi* (Stuckenberg).—Lang et al.: 128.

1951 *Sychnoelasma urbanowitschi* (Stuckenberg).—Gorsky: pl. 6.

1960 *Verneulites konincki* var. *calmisia* (Lissitzin).—Vassiljuk: 48, pl. 12, Figs. 2–2c.

1965 '*Zaphrentis*' *konincki* Vaughan.—Mitchell and Green in Green and Welch: Table 1.

1966 '*Zaphrentis*' *konincki* subsp. nov.—Mitchell and White: 46.

1972 *Sychnoelasma urbanowitschi* (Stuckenberg).—Weyer: Figs. 1–2.

1976 *Sychnoelasma urbanowitschi* (Stuckenberg).—Sayutina: 114, pl. 1, Figs. 1–7, pl. 2, Figs. 1–2.

1981 *Sychnoelasma urbanowitschi* (Stuckenberg).—Poty: 19, pl. 3, Figs. 1–9.

1986 *Sychnoelasma urbanowitschi* (Stuckenberg).—Somerville et al.: 65, Figs. 4–5.

1986 *Sychnoelasma konincki* (Milne-Edwards and Haime).—Mitchell et al.: Fig. 2.

1987 *Sychnoelasma urbanowitschi* (Stuckenberg).—Ivanowski: pl. 6, Fig. 3.

1987 *Sychnoelasma konincki* (Milne-Edwards and Haime).—Ivanowski: pl. 6, Fig. 2a–b.

*1988 *Sychnoelasma hawbankense* Mitchell and Somerville: 158, Fig. 3a–g.

1990 *Sychnoelasma urbanowitschi* (Stuckenberg).—Vuillemin: 41, pl. 1, Figs. 12–13.

1994 *Sychnoelasma urbanowitschi* (Stuckenberg).—Poty and Hannay: 59, pl. 2, Fig. 3.

2011 *Sychnoelasma hawbankense* Mitchell and Somerville.—Denayer et al.: 155, pl. 4, Fig. F.

Holotype: Specimen BGS Dw 3554 (PF 2027, PF 1269-72).

Type locality and horizon: Haw Bank Quarry, Skipton, Yorkshire, Late Tournaisian.

Diagnosis: See Mitchell and Somerville (1988).

Material: One specimen from the Esenpinar section (ULg.PA.EV.2.1).

Description: This coral is solitary (the form of the corallum was not observed), has a maximum diameter of 11 mm and 39 septa of each order at this diameter. The major septa extend to the axis and are thickened in the cardinal quadrants. They are curved and their concavity is turned toward the cardinal fossula (Fig. 3a2). In the counter quadrants, the major septa are grouped in bundles of 2–4 and joined to axial end of the cardinal fossula. The minor septa are not developed in the cardinal quadrants but are rudimentary in the counter quadrants. The cardinal septum is longer and thinner than the other septa. The counter septum is slightly shorter than the other septa. The cardinal fossula is poorly defined. In the largest section, the septa are withdrawn from the axis and a free zone is present in the centre of the tabularium. The external wall is 0.4–0.5 mm-thick.

Discussion: The size is an important specific character discriminating the species of *Sychnoelasma* (discussion in Mitchell and Green 1988). This specimen displays the dimensions and number of septa of *S. konincki* (Milne-Edwards and Haime 1851). Nevertheless, the poorly defined fossula and the curved septa remind of *S.*

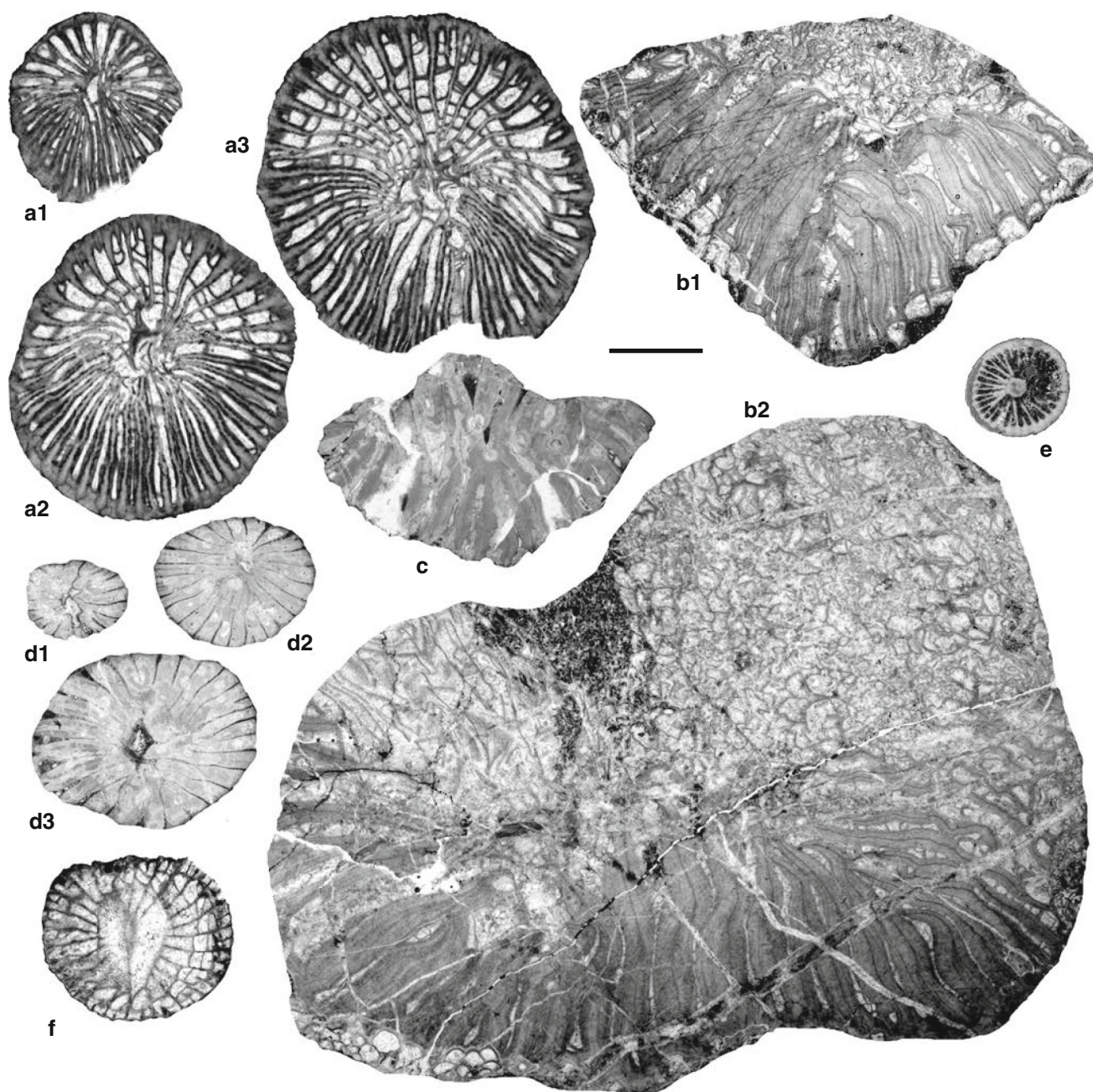


Fig. 3 *a* *Sychnoelasma hawbankense* Mitchell and Somerville 1988, *a1–a3* successive transverse sections (TS), specimen ULg.PA.EV.2.1 from Esenpınar, x5; *b–d* *Uralinia multiplex* (Ludwig 1862) from the Pelenkoğlu quarry, *b1–b2* successive TS, ULg.PA.P.3.1, x3; *c* TS, ULg.PA.P.4.4, x3, *d1–d3* successive TS, ULg.PA.P.4.5, x3;

e *Cyathaxonia cornu* Michelin 1841–1848, TS, ULg.PA.P.1.2 from the Pelenkoğlu quarry, x5; *f* *Caninia* sp., TS, ULg.PA.K.1.2 from Kokaksu, x3. Scale bar equals 5 mm for *b* and *f*, and equals 3 mm for *c*, *d* and *e*

hawbankense Mitchell and Green 1988. Our specimen is thus probably an immature specimen of *S. hawbankense* as indicated by the poorly withdrawn major septa and the rudimentary minor septa. *S. konincki* is smaller (10 mm, 35–38 septa) and typically shows a large conspicuous cardinal fossula. *S. urbanowitschi* (Stucken-berg, 1895) is larger (30–35 mm, 60–66 septa) and typically thickened.

Distribution: *S. hawbankense* is common in the Late Tournaisian and earliest Viséan (RC4 Biozone, Poty et al. 2006) in Belgium, Northern France (Poty and Hannay 1994), French Massif Central (Weyer 1972), Brittany (Vuillemin 1990) and the British Isles (Mitchell and Somerville 1988). It is also present in the Early Viséan of the Donets Basin (Vassiljuk 1960), the Ural Mountains (Sayutina 1976) and Novaya Zemlya (Gorsky 1951). In

North-western Turkey, it occurs in the Late Tournaisian of Bartın area.

Family Cyathaxoniidae Milne-Edwards and Haime 1850

Genus *Cyathaxonia* Michelin 1841–1848

Type species: *Cyathaxonia cornu* Michelin 1841–1848, Tournaisian of Tournai.

Diagnosis: See Fedorowski and Vassiljuk (2011).

Cyathaxonia cornu Michelin 1841–1848 (Fig. 3e)

*1847 *Cyathaxonia cornu* Michelin: 258, pl. 49, figs. 9-a-b.

1981 *Cyathaxonia cornu* Michelin.—Poty: 17, pl. 2, Figs. 2–5. [*cum. syn.*]

1984 *Cyathaxonia cornu* Michelin.—Rodríguez: Fig. 62.

1990 *Cyathaxonia cornu* Michelin.—Vuillemin: 34, pl. 1, Figs. 2–3.

?1990 *Cyathaxonia* sp.—Webb: 19, Figs. 9G–N.

1991 *Cyathaxonia* sp.—Fontaine et al.: 28, pl. 1, Fig. 1.

1993 *Cyathaxonia cornu* Michelin.—Weyer: 34, Fig. 3.

1994 *Cyathaxonia cornu* Michelin.—Poty and Hannay: 58.

2003 *Cyathaxonia yunnanensis* Fan in Fan et al.: p. 265, pl. 4, Figs. 8–9.

?2003 *Cyathaxonia tenuiseptata* Fan in Fan et al.: p. 264, pl. 4, Fig. 7.

?2003 *Cyathaxonia deriangmaensis* Fan in Fan et al.: p. 265, pl. 4, Figs. 3–4.

2011 *Cyathaxonia cornu* Michelin.—Denayer et al.: 154, pl. 2, Fig. G.

Holotype: Specimen figured by Michelin (1841–1848, pl. 49, Figs. 9a–b).

Type locality and horizon: Upper Tournaisian of Tournai.

Diagnosis: See Poty (1981).

Material: One specimen from the Pelenkoğlu quarry (ULg.PA.P.1.2).

Description: Small solitary coral, 3 mm in diameter, with a large axial structure. There are 34 septa of both orders. The septa are broken in the present specimen (right part of the Fig. 3e), the description is thus based on the intact part of the coral. The minor septa are long and contratingent. Both orders of septa join the axial structure. The latter has a diameter of 1 mm and is circular in transverse section. The external wall has a regular thickness of 0.4 mm.

Discussion: The present section is quite small for *C. cornu* Michelin 1841–1848 but by comparison with specimen from Belgium and France, it has a similar number of septa at this diameter. Moreover, the size of the axial structure and the thickness of the septa and external wall are also similar to those of diameter-equivalent specimens

identified as *C. cornu*. *C. rushiana* Vaughan 1906 and *C. nodosa* Fedorowski and Vassiljuk 2011, also present in the Carboniferous strata, have both a lower number of septa for a similar diameter and have thickened septa. The present specimen could therefore be considered as a juvenile *C. cornu*.

Distribution: *C. cornu* is known in the Tournaisian and Viséan of Belgium (Poty 1981), Northern France (Poty and Hannay 1994), Brittany (Vuillemin 1990), the British Isles (Mitchell 1989), in the Viséan of the Donets Basin (Vassiljuk 1960), Poland (Khoa 1977) and South-eastern China (Wu and Zhao 1989). Occurrences in the Late Carboniferous of Spain (Rodríguez 1984) and in the Permian of the Ural Mountains (Soshkina 1928) are in need of confirmation as *Cyathaxonia* is not known after the Early Carboniferous (Kossovaya et al. 2012). In Turkey, it is present in the Ivorian of Bartın (unit P1 in the Pelenkoğlu quarry).

Suborder Stauriina Verrill 1865

Family Amplexidae Chapman 1893

Genus *Amplexus* Sowerby 1814

Type species: *Amplexus coralloides* Sowerby 1814, Early Carboniferous of Ireland.

Diagnosis: See Poty (1981).

Amplexus coralloides Sowerby 1814 (Fig. 4e–f)

*1814 *Amplexus coralloides* Sowerby: 165, pl. 72.

1941 *Amplexus coralloides* Sowerby.—Hill: 148. [*cum. syn.* for Thomson's (1881) species].

1981 *Amplexus coralloides* Sowerby.—Poty: 18, pl. 2, Figs. 6–7. [*cum. syn.*]

1984 *Amplexus coralloides* Sowerby.—Poty and Onoprienko: pl. 33, Fig. 4.

1986 *Amplexus coralloides* Sowerby.—Somerville et al.: 64, Fig. 4a.

1990 *Amplexus coralloides* Sowerby.—Vuillemin: 33, pl. 1, Fig. 1.

?1990 *Amplexus* sp. – Webb: 19, Fig. 9A–F.

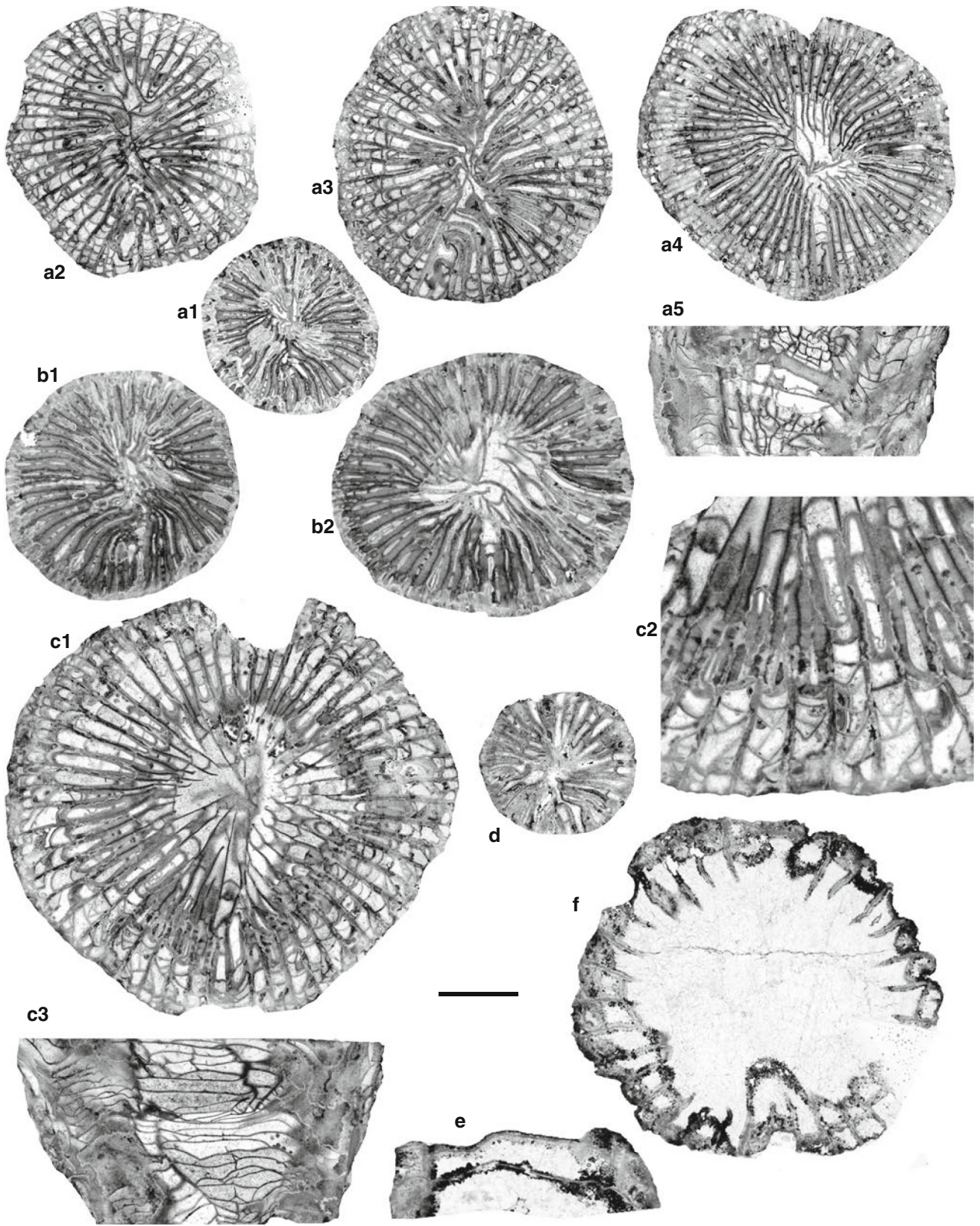
2011 *Amplexus coralloides* Sowerby.—Denayer et al.: 155, pl. 3, Figs. E, T–V, pl. 9, Figs. R–U.

Lectotype: Chosen by Smith and Thomas (1963): specimen figured by Sowerby (1814).

Type locality and horizon: Upper Tournaisian or Lower Viséan (*Syringothyris* Zone C, Waulsortian facies) of Limerick, Ireland.

Diagnosis: *Amplexus* variable in size (up to 50 mm in diameter) having up to 62 septa. After Poty (1981).

Material: Two silicified specimens from Tarla-Ağzı (ULg.PA.Ba.10 and Ba.11).



◀ **Fig. 4** *a–d* *Zaphriphyllum daleki* sp. nov., *a1–a4* successive transverse sections (TS), specimen ULg.PA.Ba.5 (holotype) from Tarla-Ağzı, x3; *a5* longitudinal section (LS), ULg.PA.Ba.5 (holotype), x3; *b1–b2* successive TS, ULg.PA.Ba.8 from Tarla-Ağzı, x3; *c1* TS, ULg.PA.Ba.2 from Tarla-Ağzı, x3; *c2* close-up view of the dissepimentarium in TS, ULg.PA.Ba.2, x6; *c3* LS, ULg.PA.Ba.2, x3; *d* TS, ULg.PA.Ba.3 from Tarla-Ağzı, x3; *e–f* *Amplexus coralloides* Sowerby 1814, *e* LS, ULg.PA.Ba.11 from Tarla-Ağzı, x4; *f* TS, ULg.PA.Ba.10 from Tarla-Ağzı, TS, x4. Scale bar equals 5 mm for *a, b, c1, c3, d*; equals 2.5 mm for *c2* and equals 3.75 mm for *e–f*

Description: The two specimens are 13 and 20 mm in diameter and have 25 and 32 septa respectively. The length of the major septa is at least 1/4 of the corallum radius. They are curved and their ends are sharp-pointed. The minor septa appear as short ridges on the internal side of the wall between the major septa. The cardinal fossula is well marked. Dissepiments are lacking. The external wall is thin and regular in thickness. The tabulae are complete, mesa-shaped or domed in the central part and spaced (4.5 mm between two tabulae in one of our specimens).

Discussion: These specimens share the characteristic features of *A. coralloides* Sowerby 1814 but their cardinal fossula is better defined than in the type material. However, after Poty (1981), it is a common variation in this species. **Distribution:** *Amplexus coralloides* is documented from the Lower Carboniferous of Belgium (Poty 1981), Brittany (Vuillemin 1990), Britain (Mitchell 1989), Scotland (Hill 1938–1941), Ireland (Somerville 1994), Germany (Weyer 2000), south-western Spain (Rodríguez and Falces 1994), the Donets Basin (Vassiljuk 1960), the Kuznetsk Basin (Dobroľjubova et al. 1966), the Ural Mountains (Gorsky 1938), Kazakhstan (Ivanowski 1967), the Omolon Massif (Poty and Onoprienko 1984), South-eastern China (Poty and Xu 1996), Japan (Minato 1955), North America (Easton 1944) and possibly Eastern Australia (Webb 1990).

Suborder Caniniina Wang 1950

Family Cyathopsidae Dybowski 1873

Genus *Caninia* Michelin in Gervais 1840

Type species: *Caninia cornucopiae* Michelin in Gervais 1840, Tournaisian of Tournai.

Diagnosis: See Hill (1981).

Caninia sp. (Fig. 3f)

Material: Two specimens from the disused quarry near the Kokaksu section.

Description: Small *Caninia*, 7 mm in diameter, having 24–26 septa of each order. The major septa are long (1/3 of the corallum radius) and slightly wavy. The minor septa are rudimentary. The cardinal septum is shorter than the others. The dissepimentarium is rudimentary and composed of a

single discontinuous row of interseptal dissepiments. The external wall is wavy.

Discussion: These small-sized specimens are similar to the small *Caninia* known from the upper Tournaisian of Tournai (see Denayer et al. 2011, pl. 3, Figs. T–V), sharing the same dimensions, number of septa and poorly developed minor septa.

Distribution: *Caninia* sp. was collected in the massive limestone exposed in the disused quarry south of the Kokaksu section. This limestone yielded foraminifers typical of the late Tournaisian MFZ6 Biozone of Poty et al. (2006).

Genus *Uralinia* Stuckenberg 1895

Type species: *Heliophyllum multiplex* Ludwig 1862, Tournaisian of the Ural Mountains (= *Pseudouralinia gigantea* Yü 1933).

Diagnosis and discussion: See Poty and Boland (1994) and Denayer (accepted).

Uralinia multiplex (Ludwig 1862) (Fig. 3b–d)

*1862 *Heliophyllum multiplex* Ludwig: 199.

2014 *Uralinia multiplex* (Ludwig).—Denayer: Fig. 6A–C, 7A. [*cum. syn.*].

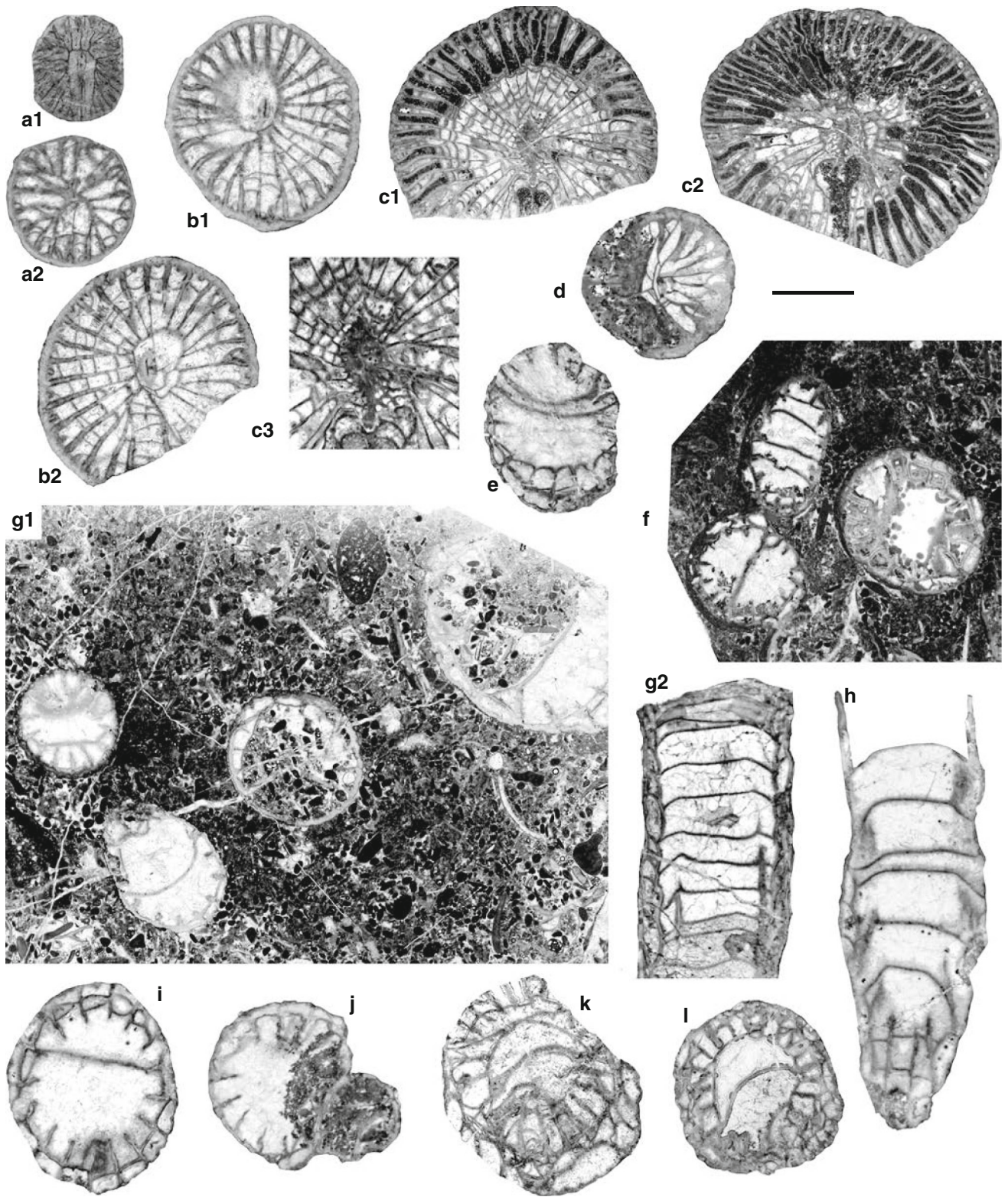
Holotype: Specimen GZG.INV.030.534 of Ludwig collection, Göttingen, Germany.

Type locality and horizon: Upper Tournaisian of the Ural Mountains.

Diagnosis: See Poty (2002).

Material: Seven specimens from the Pelenkoğlu quarry (ULg.PA.P.3.1, P.4.1, P.4.2, P.4.3, P.4.4, P.4.5, P.4.6) and four from the Esenpınar section (ULg.PA.EV.1.1.I, EV.1.1.III, EV.1.5, EV.1.6). Many crushed and fragmented specimens were also collected in the Dallica section.

Description: The largest observed corallum is 70 mm in diameter and has 45 major septa in the cardinal quadrants. The juvenile (late neanic) stage is characterized by septa thickened in all quadrants of the tabularium and by a dissepimentarium absent or rudimentary (Fig. 3d1–d3). The septa withdraw from the axis in the counter quadrants where the tabularium is larger than 10 mm. In the mature stage, the septa are atrophied and often lacking in the counter quadrants. In the cardinal quadrants, there are 10–15 short thick septa (up to 2 mm-thick), tortuous and sharp-pointed in transverse section. The minor septa are not developed. The cardinal septum is usually short and the cardinal-lateral septa are curved toward the fossula. In the cardinal quadrants, the dissepimentarium is composed of few interseptal dissepiments and numerous rows of lonsdaleoid dissepiments. In the counter quadrants, the dissepimentarium is made of irregular globose and vesiculous lonsdaleoid dissepiments (Fig. 3b2).



◀ **Fig. 5** *a–b* ‘*Lophophyllum*’ *konincki* Milne-Edwards and Haime 1851, *a1–a2* successive transverse section (TS), specimen P.3.3.II from the Pelenkoğlu quarry, x6; *b1–b2* successive TS, ULg.PA.P.3.3.I from the Pelenkoğlu quarry, x6; *c* *Cyathoclisia uralensis* Sayutina 1970, *c1–c2* successive TS, ULg.PA.P.3.2.II, x3; **c3** close-up view of the axial structure in TS, ULg.PA.P.3.2.II, x6; *d* *Amygdalophyllum?* sp., TS, ULg.PA.ET.8b.1.II from Topluca, x6; *e–j* *Corphalia fourmarieri* (Charles 1933), *e* TS, ULg.PA.KR.3.d’ from Kokaksu, x4; *f* TS, ULg.PA.G.13.5.a from Gökgöl, TS, x4; *g1* TS, ULg.PA.IP-10861-11 from Gökgöl (lectotype, figured by Charles 1933, pl. 6, fig. 45), x4; *g2* LS, ULg.PA.IP-10861-11 form Gökgöl (lectotype, figured by Charles 1933, pl. 6, fig. 46), x4; *h* LS, ULg.PA.G.13.5.c from Gökgöl, x4; *i* TS, ULg.PA.G.13.5.e from Gökgöl, x4; *j* TS of a corallite with its lateral offset, ULg.PA.G.13.5.a from Gökgöl, x4; *k–l* *Corphalia* sp., *k* TS, ULg.PA.ET.9.2 from Topluca, x4; *l* TS, ULg.PA.ET.9.3 from Topluca, x4. *Scale bar* equals 5 mm for *c1–c2*; equals 2.5 mm for *a1–a2*, *b1–b2*, *c3* and *d*; and equals 3.75 mm for *e–l*

Discussion: The characters of the tabularium, observed in both juvenile and mature stages are those of *Uralinia multiplex* (Ludwig 1862). The size and number of septa also correspond to those of this species. The dissepimentarium is eroded in almost all specimens from Esenpınar and the Pelenkoğlu quarry but the specimen ULg.PA.P.3.1 (Fig. 3b1–b2) is sufficiently well preserved to identify the species *U. multiplex*. The dimensions and number of septa of the mature stages allows to discriminate our specimens from *U. lobata* Poty and Boland 1994 and *U. uralica* (Rogozov 1960) that are both smaller and have a narrower dissepimentarium. The juvenile specimens can be distinguished from juvenile stage of *Keyserlingophyllum obliquum* (Keyserling 1846) by the disposition of the septa (pinnate around the alar fossula in this genus).

Distribution: *Uralinia multiplex* is a guide taxa for the Ivorian and is known from Belgium (Poty 1989; biozone RC3 α of Poty et al. 2006), Poland (Poty et al. 2003), the Omolon Massif (Onoprienko 1979), the Ural Mountains (Ludwig 1862), Novaya Zemlya (Gorsky et al. 1975), South China (Poty and Xu 1996) and in the Central Taurides (South Turkey, Denayer, accepted). In north-western Turkey, *U. multiplex* is present in lithological unit P3 of the Pelenkoğlu quarry, together with ‘*Lophophyllum*’ *konincki* and *Cyathoclisia uralensis* in levels dated of the late Tournaisian MFZ5 Biozone. A second, younger horizon yielded many fragments and juveniles of the species and appears as a marker bed in the Bartın area, recognized in Pelenkoğlu, Esenpınar and Dallica sections.

Family Lophophyllidae Grabau 1928

Genus ‘*Lophophyllum*’ Milne-Edwards and Haime 1850

Type species: *Lophophyllum konincki* Milne-Edwards and Haime 1851, Tournaisian of Tournai.

Diagnosis: Small solitary ceratoid coral with an oblique calyx and conspicuous bilateral symmetry. Columella elongated, connected to the cardinal and counter septa in

juvenile stages, only to the counter septum in mature stages. Major septa long, excepted for the cardinal-lateral, short and contratingent. In the cardinal quadrants, septa sagging toward the cardinal fossula or confluent with the columella. In the counter quadrants, septa straight and withdrawn from the axis. Minor septa rudimentary, slightly longer in the cardinal quadrants. Cardinal fossula well-marked, situated in the convex side of the corallum. No dissepiments. Tabulae domed. Modified after Hill (1981).

Discussion: The genus *Lophophyllum* Milne-Edwards and Haime 1850 is enigmatic. Initially defined on the calicular characters and not figured in the original publication, it led to many questionable interpretations. In the introductory note of its revision of the genus, Lecompte (1955) noted that the genus *Lophophyllum* has often been misinterpreted and became almost meaningless and unusable because the knowledge of the type material is very weak. The situation has not changed since Lecompte’s revision and search for topotypes failed until recently (Poty 2007b). Lecompte (1955) provided a good summary of the controversy concerning the distinction between the species *L. konincki* Milne-Edwards and Haime 1851—with no dissepiments, interpreted by Lecompte (1955) as a juvenile stage—and *L. tortuosum* (= *Cyathaxonia tortuosa* Michelin 1841–1848) having dissepiments and interpreted as a mature stage. After Lecompte (1955), *L. konincki* and *L. tortuosum* would represent different stages of one single species. Dissepimented specimens of the *L. tortuosum* Michelin 1841–1848 group are in part covered by the diagnosis of the genus *Eostroton* Vaughan 1915 and only have an external habitus in common with *Lophophyllum*. The affinity of undissepimented forms is still debatable. After Poty and Xu (1996), specimens of the *L. konincki* group correspond possibly to juvenile stages of *Caninia cornucopiae* Michelin in Gervais 1840. Re-investigation of recently collected topotypes of *L. konincki* from Tournai led Poty (2007b) to suggest that *L. konincki* could be the undissepimented juvenile stage of *Caninia cornucopiae* but the strong morphological and ontogenic variability of the latter prevent a clear definition. The specific characters (see diagnosis below) of *L. konincki* (and consequently of the genus *Lophophyllum*) are included in the variability of juveniles stages of *Caninia cornucopiae* and *Eostroton tortuosum*. A revision of the ontogeny of these three species is necessary. Meanwhile, the name ‘*Lophophyllum*’ is here used in inverted commas.

‘*Lophophyllum*’ *konincki* Milne-Edwards and Haime 1851 (Fig. 5a–b)

*1851 *Lophophyllum konincki* Milne-Edwards and Haime: 349, pl. 3, Fig. 4.

1872 *Lophophyllum konincki* Milne-Edwards and Haime.—de Koninck: pl. 4, Fig. 3.

?1930 *Zaphrentis* sp.—Lewis: pl. 22, Fig. 16a–b.

1955 *Lophophyllum konincki* Milne-Edwards and Haime.—Lecompte: 411, pl. A, Figs. 1–4, 7.

?1955 *Lophophyllum konincki* Milne-Edwards and Haime.—Lecompte: 411, pl. A, Fig. 5.

(non) 1989 *Lophophyllum konincki-tortuosum*.—Poty: Fig. 3D.

2005 ?*Lophophyllum* sp.—Chwieduk: 415, pl. 9, Figs. 1–3.

2011 *Lophophyllum konincki* Milne-Edwards and Haime.—Denayer et al.: 155, pl. 3, Figs. G–H.

Lectotype: Milne-Edwards and Haime's (1851) holotype is lost. The lectotype, designated by Carruthers (1913), is a topotype of Milne-Edwards collection (Museum national d'Histoire naturelle, Paris, France), figured by Lecompte (1955), pl. A, Fig. 2a–b).

Diagnosis: *Lophophyllum* 10–15 mm-high, with 9–13 mm in diameter, having 30–32 major septa. Septa disposed in a zaphrentoid pattern in the cardinal quadrants and radially disposed in the counter quadrants. Cardinal fossula closed, embracing the columella or withdrawn toward the periphery. Modified from Lecompte (1955).

Material: Two specimens from the Pelenkoğlu quarry of Esenpinar (ULg.PA.P.3.3.I, P.3.3.II).

Description: The smallest observed section is 3 mm in diameter and shows 18 thick septa disposed in a zaphrentoid pattern (Fig. 5a1). The fossula is elongated and extends to the counter quadrants. It is completely closed by the cardinal-lateral septa, the other major septa joining these cardinal-lateral septa near the axial end of the fossula (Fig. 5a2). In a 4.5 mm wide section, the septa are thinner than in the previous stage and are grouped in four bundles separated by the proto-septa. In sections with a diameter larger than 5 mm, there are 27 septa, curved toward the cardinal fossula in the cardinal quadrants but radially disposed in the counter quadrants. The cardinal-lateral and alar septa are sagging toward their counter neighbours. The minor septa are short and firstly develop in the cardinal quadrants (Fig. 5b1) then in the counter quadrants. The cardinal septum is long, thin and joined with the columella whilst the counter septum is disconnected in mature stages. The columella is spindle-shaped, 1.2 mm long and 0.6 mm wide. A dark median line is conspicuous in the central part of the columella (Fig. 5b2). The dissepimentarium is lacking. The external wall has a regular thickness of 0.5 mm.

Discussion: These specimens have the dimensions and number of septa of the topotypes of '*Lophophyllum konincki* Milne-Edwards and Haime 1851' figured by Lecompte

(1955). They are also strongly similar in size and morphology to the specimens of '*L. konincki* from the Late Tournaisian of Tournai.

Distribution: '*Lophophyllum konincki* occurs in the Ivorian of Belgium (Poty 1989; Denayer et al. 2011) and possibly in Poland (Chwieduk 2005). In Turkey, it is known from the Pelenkoğlu quarry (Bartın) where it occurs with *Uralinia simplex* and *Cyathoclisia uralensis* in the Ivorian.

Family Aulophyllidae Dybowski 1873

Subfamily Amygdalophyllinae Grabau 1935

Genus *Cyathoclisia* Dingwall 1926

Type species: *Cyathoclisia tabernaculum* Dingwall 1926, Tournaisian of England.

Diagnosis: See Poty (1981).

Discussion: Hill (1981) classified *Cyathoclisia* in the subfamily Clisiophyllinae but the morphology of the axial structure and the conical tabulae are more typical of the Amygdalophyllinae. Weyer (2006) subdivided the *Cyathoclisia* in two sub-genera: *Cyathoclisia* (*Cyathoclisia*) Dingwall 1926 and *Cyathoclisia* (*Clisaxophyllum*) Grabau in Chi 1931. *Clisaxophyllum* is characterized by minor septa short and not contratingent, and consequently a tabularium which is not biform. In the original description of Grabau in Chi (1931), the most distinctive feature of *Clisaxophyllum* is the occurrence of axial tabellae forming a 'wall' around the axial structure. These last characters are not present in *Cyathoclisia* and thus put in doubt the taxonomic relationships of *Cyathoclisia* and *Clisaxophyllum*. Moreover, *Cyathoclisia* is known in the Late Tournaisian while *Clisaxophyllum* is Late Carboniferous in age but no intermediate form is present in the Viséan and Serpukhovian. Contrary to Weyer's (2006) opinion, *Cyathoclisia* and *Clisaxophyllum* have to be considered as two distinct genera, morphologically and taxonomically close, but different.

Cyathoclisia uralensis Sayutina 1970 (Fig. c)

p.p. 1960 *Cyathoclisia modavensis* (Salée).—Soshkina: 282, pl. 1, Figs. 5–7.

p.p. 1966 *Cyathoclisia densusum* (Gorsky).—Dobroljubova et al.: 42, pl. 3, Fig. 3.

1967 *Cyathoclisia tatarica* Altmark: 106, pl. 13, Figs. 1–3.

*1970 *Cyathoclisia tabernaculum uralensis* Sayutina: 40, pl. 3, Figs. 3–5.

1973 *Cyathoclisia tabernaculum uralensis* Sayutina.—Sayutina: 65, pl. 5, Figs. 3–5.

1984 *Cyathoclisia modavensis* (Salée).—Poty and Onoprienko: 44, pl. 19, Figs. 1–5.

2003 *Cyathoclisia uralensis* Sayutina.—Poty et al.: 105, pl. 3, Figs. 1, 9.

2005 *Cyathoclisia modavensis* (Salée).—Chwieduk: 423, pl. 12, Fig. 2.

2011 *Cyathoclisia* cf. *soshkinae* Sayutina.—Denayer et al.: 166, pl. 2, Fig. H.

Holotype: Specimen 2706/253, Tournaisian of the Ural Mountains, figured by Sayutina (1970), pl. 3, Fig. 3).

Diagnosis: *Cyathoclisia* reaching a diameter of 36 mm and having up to 60 septa of each order. Major septa thick in the cardinal part of the tabularium. Minor septa half as long as the majors and often contratingent. Axial structure composed of a short and thick axial plate bearing long twisted septal lamellae, sometimes connected to the axial ends of major septa. Dissepimentarium composed of interseptal and seldom second order lonsdaleoid dissepiments. Modified after Sayutina (1970).

Material: One specimen from the Pelenkoğlu quarry (ULg.PA.P.3.2.I).

Description: Solitary corallum with a maximum diameter of 15 mm (13.5 mm for the tabularium) having 42 septa of each order. The major septa are long and confluent to the axial structure. They are straight and thin in the dissepimentarium but twisted in the inner tabularium. The minor septa are long (more than half the length of the major septa) and typically contraclinant. In the counter quadrants, the minor septa enter into the tabularium on less than 1 mm and in the cardinal quadrants they can extend up to 2 mm into the tabularium (Fig. 5c1–c2). The cardinal septum is short, located in an open keyhole-shaped cardinal fossula and edged by thickened cardinal-lateral septa. In the cardinal quadrants, the septa are curved toward the fossula. The axial structure is made of a thick (up to 0.7 mm) spindle-shaped axial plate connected to numerous septal lamellae continuous with the major septa (Fig. 5c3), and axial tabulae with upturned edges. The dissepimentarium is narrow, composed of one or two incomplete rows of concentric interseptal dissepiments. The wall has a regular thickness of 0.4 mm.

Discussion: *Cyathoclisia uralensis* Sayutina 1970 differs from *C. modavensis* (Salée 1913) by its smaller dimensions (30–35 mm of diameter and 60 septa versus 45 mm and 80 septa), its major septa not divided longitudinally and its simpler axial structure. Moreover, *C. uralensis* has shorter minor septa, a narrower dissepimentarium and has rare second order lonsdaleoid dissepiments. *C. soshkinae* Sayutina 1970 is similar to *C. uralensis* but has only one row of dissepiments, an axial structure commonly reduced to a thickened axial plate with few or no septal lamellae and short minor septa. *C. carinata* Rogozov 1963 is distinguished by its carinated septa.

Distribution: *Cyathoclisia uralensis* is the oldest species of the genus (lower part of Ivorian substage, RC3 α Biozone of

Poty et al. 2006). It occurs in Belgium (Poty et al. 2006), in the Ural Mountains (Sayutina 1973), in the Omolon Massif (Poty and Onoprienko 1984) and in Poland (Poty et al. 2003; Chwieduk 2005).

Family Ekvassophyllidae Hill 1981

Genus *Zaphriphyllum* Sutherland 1954

Type species: *Zaphriphyllum disseptum* Sutherland 1954, Viséan of Alaska.

Diagnosis: Trochoid solitary coral with numerous septa extending up to the axis in the mature stages. Septa arranged in bundles curved toward the cardinal fossula but radially arranged in the counter quadrants. Cardinal septum short. Minor septa well developed, sometimes contratingent. Dissepimentarium composed of concentric—or more rarely herringbones—interseptal dissepiments. Second order lonsdaleoid dissepiments occasional in mature stages. Inner row of dissepiments usually thickened. Deep cardinal fossula on the concave side of the corallum. Tabulae domed, sagging towards the fossula. Emended of Semenoff-Tian-Chansky (1974).

Discussion: *Zaphriphyllum* Sutherland 1954 is characterised by long major and minor septa, a well-developed dissepimentarium and a deep cardinal fossula. The lack of an axial column and the presence of dissepiments allow the distinction of *Zaphriphyllum* from other solitary corals with a zaphrentoid septal pattern and a deep fossula. Moreover, the zaphrentoid pattern is a character distinguishing *Zaphriphyllum* from caniniid corals having long septa. Sutherland (1954), noticing the morphological similarity of *Zaphriphyllum* and *Amplexizaphrentis* Vaughan, 1906, classified both genera in the family Hapsiphyllidae. Semenoff-Tian-Chansky (1974) challenged this attribution because the cardinal fossula of *Zaphriphyllum* is situated on the concave side of the corallum while it is on the convex side in *Amplexizaphrentis*. Hill (1981) followed Semenoff-Tian-Chansky and included the genus in her new family Ekvasophyllidae. *Zaphriphyllum* is occasional in the Late Tournaisian and Early Viséan of South China Poty and Xu (1996), the Sahara (Semenoff-Tian-Chansky 1974), North Iran (Khaksar 1996), North America (Sando 1960) and the British Isles (Poty 2007a).

Zaphriphyllum daleki sp. nov. (Figs. 4a–d, 6)

Etymology: The species dedicated to the Daleks (science-fiction character).

Holotype: Specimen ULg.PA.Ba.5 - Bartin 2009.

Type locality and horizon: Tarla-Ağzi, north of Bartin, along the path from the village to the weather radar house; from a horizon attributed to the Late Tournaisian (by

correlation with the Topluca section) within the Yılanlı Formation

Diagnosis: Large-sized *Zaphriphyllum* 21–30 mm in diameter, having more than 40 septa of each order in mature stages. Major septa long but leaving a central free zone up to 1/4 of the corallum diameter. Dissepimentarium composed of 3–8 rows of concentric, angulo-concentric and herringbone interseptal dissepiments.

Material: Twelve silicified rock-free specimens, including the holotype, from Tarla-Ağzı (ULg.PA.Ba.1, Ba.2, Ba.3, Ba.4, Ba.5, Ba.6, Ba.7, Ba.8, Ba.9, Ba.12, Ba.13, Ba.14, Ba.15).

Description: Trochoid, ceratoid and cerato-cylindric corallum 20–50 mm high with a maximum diameter of 30 mm (Fig. 6). The calyx is shallow, marked by a narrow but deep cardinal fossula situated on the concave side of the corallum. The external wall is marked by rugae. In transverse section, the mature characters appear where the diameter reaches 21 mm. The tabularium diameter is 14 mm on average (maximum 24 mm). There are 44 septa

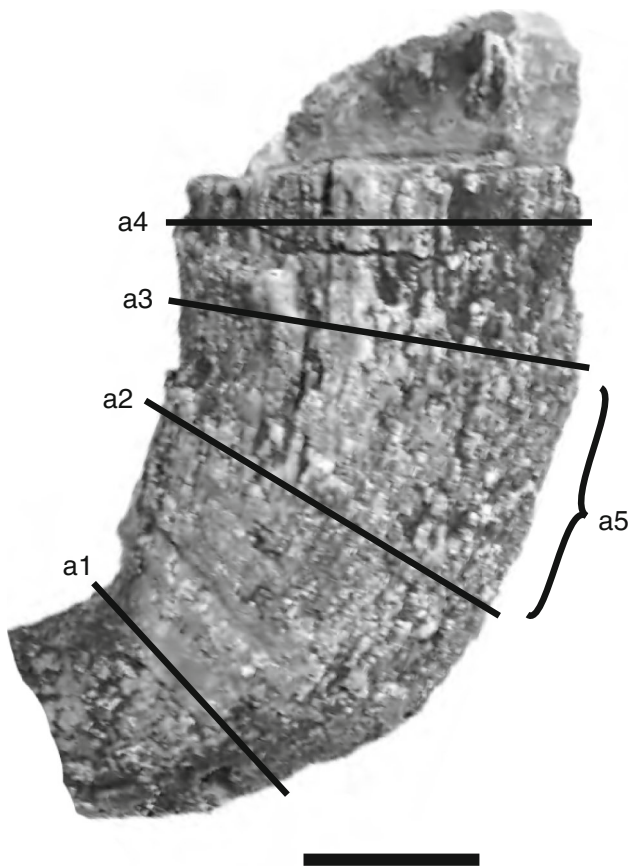


Fig. 6 Macroscopic view of the holotype of *Zaphriphyllum daleki* sp. nov. (specimen ULg.PA.Ba.5) with position of the transverse and longitudinal sections (Fig. 4 a1–a5). Scale bar equals 5 mm

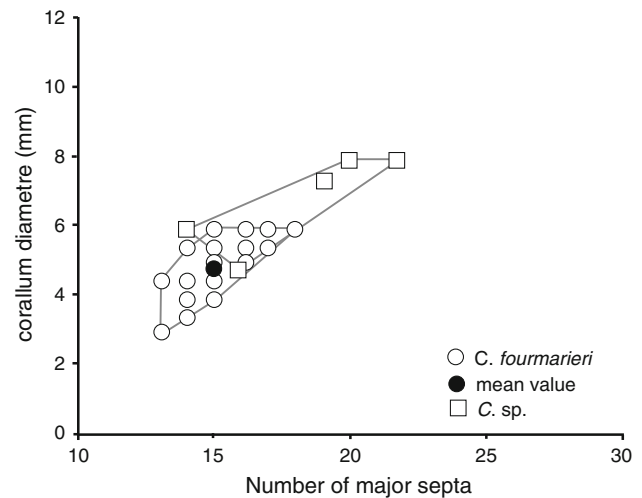


Fig. 7 Scatter diagram showing the number of septa plotted against corallum diameter for *Zaphriphyllum daleki* sp. nov

of each order (maximum 52, Fig. 7). In juvenile stages, the major septa are spindle-shaped and long. The major septa usually reach the axis and some of them fuse in bundles (Fig. 4a1, b1). In mature stages, the septa are withdrawn from the axis and leave a septa-free central zone with a diameter varying between 1/5 and 1/4 of the corallum diameter (Fig. 4b2). The septa are arranged in bundles, curved in the cardinal quadrants but radially disposed in the counter quadrants. Their axial ends are sharp. The minor septa are variably developed and are commonly longer in the counter quadrants than in the cardinal ones and may be contratingent (Fig. 4a4). They are thinner than the major. The cardinal septum is shorter, thicker and tortuous. The cardinal fossula is open toward the tabularium and marked by the withdrawal of the dissepimentarium toward the periphery. The fossula tends to narrow in mature stages. The dissepimentarium is composed of 3–8 rows of concentric, angulo-concentric and herringbones interseptal dissepiments (Fig. 4c2). The inner row of dissepiments is sometimes thickened. The dissepiments are 1 mm high and 2–3 mm long in longitudinal section. They are steeply inclined toward the tabularium. The external wall is 0.3 mm-thick and wavy. In longitudinal section, the tabulae are complete or divided, flat or axially depressed (Fig. 4c3). There are 16–18 tabulae per centimetre height. Discussion: Two *Zaphriphyllum* species show similar dimensions: *Z. shidianense* Duan 1985 (16–20 mm for 43–46 septa) and *Z. latidissepimentarium* Wang 1985 (20 mm for 52 septa). Both have also very thick septa in juvenile stages that become thin in the mature stages. *Z. daleki* differs by its relatively longer minor septa (sometimes contratingent) and a larger dissepimentarium (less than 5 rows in *Z. shidianense* and *Z. latidissepimentarium*). *Z. mobarakense* Khaksar 1996, *Z. lavocati* Semenoff-Tian-

Chansky 1974 and *Z. crassiaxum* Semenoff-Tian-Chansky 1974 are all smaller and have less septa. Poty (2007a) identified *Z. cf. lavocati* in the Late Tournaisian of Wales (RC3 γ subzone) which has the dimensions and number of septa of *Z. daleki* sp. nov. but the central zone of the tabularium is larger in the British specimens (it may be the result of sections under tabulae where the septa are commonly withdrawn).

Distribution: *Zaphriphyllum daleki* sp. nov. was collected in Tarla-Ağzı in strata attributed to the Late Tournaisian by correlation with the Topluca and Esenpınar sections. Unfortunately, no precise age is available for this horizon since *Amplexus coralloides* is the only other taxa occurring in this locality while foraminifers are lacking.

Family unspecified

Genus *Corphalia* Poty 1975

Type species: *Corphalia mosae* Poty 1975, Lower Viséan of Corphalie, Belgium.

Diagnosis: See Poty (1975).

Discussion: Poty (1975) noticed the morphological similarity of *Corphalia mosae* Poty 1975 with protocorallites of *Dorlodotia briarti* Salée 1920. Poty (1981, 1993) interpreted *Corphalia* as evolving from *Dorlodotia* by progenesis. However, since the discovery of *Corphalia* in the Late Tournaisian (Poty et al. 2003), *Dorlodotia* cannot be considered as the ancestor and Poty's model should be turned around. *Corphalia* appeared during the Avins event in the latest Tournaisian (latest Ivorian RC4 β 1 Biozone, Poty 2007a). Limited increase (occasional offset) is observed in specimens of *Corphalia* sp. figured by Poty et al. (2003) and in the specimen figured in the present Fig. 5j. *Corphalia* might have given rise to *Dorlodotia* after it developed a persistent increase at the end of the Tournaisian. *Dorlodotia* sp. occurring in the top of the RC4 β 1 Biozone in the Visé area, Southern Belgium (Denayer et al. 2011, plate 5, figure V) is the oldest species of *Dorlodotia* and is contemporaneous with *Corphalia*. *Corphalia* also resembles the corallites of some small-size *Kwangisiphyllum* but the relationships of *Kwangisiphyllum*, *Corphalia* and *Dorlodotia* are still unclear.

Corphalia fourmarieri (Charles 1933) (Fig. 5e-j)

*1933 *Diphyphyllum fourmarieri* Charles: 139, pl. 6, Figs. 45–46.

Lectotype: Here designated as specimen IP-10861-11, Charles collection (Royal Institute of Natural Sciences of Belgium, Brussels).

Plesiotypes: specimen ULg.PA.KR.3.d.I and KR.3.3.I from Kokaksu; specimen ULg.PA.G.13.5.e.I from Gökgöl. The diagnosis is based on the plesiotypes.

Type locality and horizon: After Charles (1933): Asma hamlet, (3 km south-east of Zonguldak) about 150 metres upstream the waterfall of the Gökgöl creek. This locality was identified as the Gökgöl section, Zonguldak vicinity, North-western Turkey. Yılanlı Formation, the bioclastic limestone with oncoïds exposed in the Gökgöl section (unit G.13.c) and in the Kokaksu section (unit KR.3), Late Ivorian (MFZ8 foraminiferal Biozone of Poty et al. 2006). Material: More than 50 specimens from both localities (numerous specimens in the samples labelled ULg.-PA.KR.3.1.I, KR.3.2.1, KR.3.2.2, KR.3.3, KR.3.d, G.13.5). Diagnosis: *Corphalia* with a mean diameter of 5 and 15–20 mm-high, having 15–16 septa. Major septa cuneiform with a thickened base. Minor septa not developed. Dissepimentarium composed of one incomplete row of concentric interseptal dissepiments and one incomplete row of lonsdaleoid dissepiments. External wall 0.15 mm thick and wavy.

Description: The coralla have an average diameter of 5.1 mm (maximum 6 mm), the tabularium is 4 mm large on average. There are 14–17 major septa (average: 15, Fig. 8). The septa are short (less than 1/3 of the corallum radius), straight or rarely sinuous and have a thick cuneiform base. The minor septa are not developed but appear as folds on the inner side of the external wall (Fig. 5i). There are no axial structure and fossula. The dissepimentarium is composed of one incomplete (often half) row of concentric interseptal dissepiments, sometimes thickened and forming a stereozone with the thickened septa (Fig. 5g, i). The lonsdaleoid dissepiments form a discontinuous peripheral row. The external wall is 0.2–0.3 mm thick, usually wavy or festooned. In longitudinal section, the tabulae are

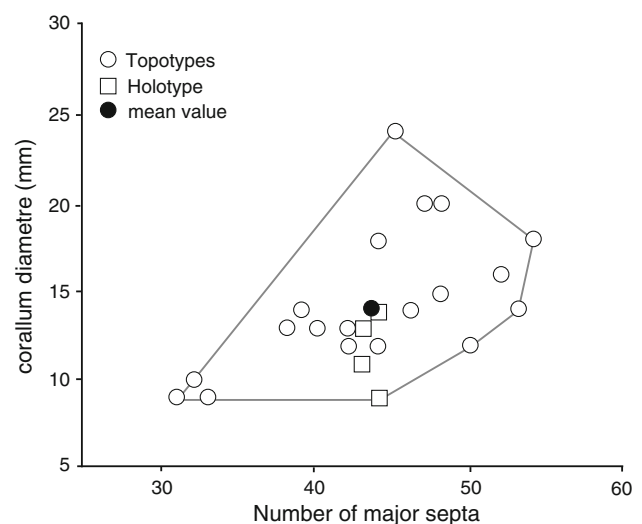


Fig. 8 Scatter diagram showing the number of septa plotted against corallum diameter for *Corphalia fourmarieri* (Charles 1933) and *Corphalia* sp

complete, mesa-shaped and spaced regularly (Fig. 5g2, h). The dissepiments are steeply inclined (up to 70°), 0.4–0.6 mm large and 1–1.2 mm high. There are 10 tabulae and 10–12 dissepiments per centimetre height.

Discussion: Charles (1933) described this species under the name *Diphyphyllum fraiponti* but the corals are solitary and not colonial as this authors supposed. One specimen among the 50 observed shows a small offset (Fig. 5j). Except for this limited increase, the Turkish specimens fit with the definition of *Corphalia* as defined by Poty (1975). They differ from the species *C. mosae* Poty 1975 from the Early Viséan of Belgium by having a slightly smaller diameter (5 mm versus 6 mm for *C. mosae*) and a slightly smaller number of septa (15 versus 17 on average). Moreover, the external wall is less festooned and the dissepimentarium is more regular than in the *C. mosae*. Specimens figured under the name *Dorodotia* sp. by Poty et al. (2003) from the Latest Ivorian (RC4β1 Biozone) of Belgium and Poland are both larger and have more septa than *C. fourmarieri*. The Polish specimen also shows an offset.

Distribution: *C. fourmarieri* is only known from the type-horizon in Gökgöl and Kokaksu in the latest Tournaisian (RC4β1 and MFZ8 biozones).

Corphalia sp. (Fig. 5k–l)

Material: Two specimens from the Topluca section (Ulg.-PA.ET.9.2, ET.9.3).

Description: The coralla have a diameter of 8 and 10 mm and 22 and 24 septa, respectively. The major septa are short and thick, their bases are cuneiform. The minor septa are not developed. The cardinal fossula is conspicuous in one specimen (Fig. 5k) but not in the other. The dissepimentarium is composed of 1–2 rows of lonsdaleoid dissepiments and one incomplete row of concentric interseptal dissepiments. The wall is thick and arched (Fig. 5l).

Discussion: Base on their morphology and solitary habitus, these specimens can be confidently attributed to *Corphalia*. They however differ from *C. fourmarieri* (Charles 1933) by a higher and number of septa and a larger size, which make them more similar to *C. mosae* Poty 1975 and *C. sp.* (sensu Denayer et al. 2011). Nevertheless, their arched wall differs from the latter species. The material is unfortunately too limited to understand the morphological variability and to compare it to that of *C. mosae* and *C. fourmarieri*. We thus prefer to use an open nomenclature rather than creating a new species.

Distribution: *Corphalia* sp. was collected in the Topluca section in unit ET9a, dated by foraminifers of the (MFZ6?)-MFZ7 biozones, i.e. the upper part of the Ivorian. *Corphalia* sp. is consequently slightly older than *C.*

fourmarieri and then the Polish and Belgian specimens attributed to *Corphalia* sp.

Biostratigraphy

The rugose coral biozones defined by Poty (1985) and emended by Poty et al. (2006) were recognized in north-western Turkey (Fig. 2). Yet, not all the biozones were identified in Turkey. The oldest coral association, including *Cyathaxonia cornu*, '*Lophophyllum*' *konincki*, *Uralinia multiplex* and *Cyathoclisia uralensis* is correlated with the RC3 Biozone. The three subzones of the RC3 Biozone were not recognized because the guide taxa are lacking in the investigated areas. By comparison with Western Europe where *Cyathoclisia uralensis* and *Uralinia multiplex* are characteristic for the RC3α, our first association could correspond to the lower subzone. Nevertheless, '*Lophophyllum*' *konincki* is not confidently known so early in Belgium since it appears in the upper part of the Tournai Formation, which is possibly correlated with the RC3β (Poty et al. 2006). This *Cyathoclisia uralensis*-'*Lophophyllum*' *konincki*-*Uralinia multiplex* can be correlated with the *Uralinia multiplex* assemblage and with the base of the *Kueichouphyllum alborense* assemblage defined in the Taurides (south Turkey, Denayer, accepted). The latter two assemblages that are dominated by the widely distributed genera *Bifossularia*, *Calmiussiphyllum*, *Caninia*, *Caninophyllum*, *Keyserlingophyllum*, *Siphonophyllia*, *Uralinia* and *Zaphrentites* as well as the Asian genus *Kueichouphyllum*. Similar associations are known from shallow-water facies in Iran (Heravi and Kakhsar 1999; Ogar et al. 2013).

Sychnoelasma hawbankense is the guide taxon for the RC4 Biozone. The subzone RC4α is characterized in north-western Turkey by a low diversity coral assemblage of *Sychnoelasma hawbankense*, *Caninia* sp., *Amplexus coralloides* and *Zaphriphyllum daleki* sp. nov. The latter two are not well constrained by biostratigraphy but we include them in this zone because *Zaphriphyllum* is not known in strata older than mid-late Ivorian in Western Europe (Poty 2007a), China (Wu and Zhao 1989) and Northern Africa (Semenoff-Tian-Chansky 1974). *Zaphriphyllum* is the only taxon also present within the time-equivalent *Keyserlingophyllum-Dorlodotia* interval zone of Tan et al. (1987) of South China. No equivalent assemblage was observed in the Turkish Taurides (Denayer, accepted).

The first appearance of *Corphalia* in the Bartın area (*Corphalia* sp.) and Zonguldak area (*C. fourmarieri*) allows the definition of the base of the RC4β1 subzone. The other coral of this subzone found in the investigated areas is a juvenile stage attributed with a query to

Amygdalophyllum? sp. (Fig. 5d). *Corphalia* sp. occurs in levels of MFZ7-8 age and could consequently be slightly older than *C. fourmarieri* and the Tournaisian species of this genus in Europe. The fossiliferous horizon described in the Hakkari area (Arabian Plate, south-eastern Turkey) by Denayer and Hoşgör (2014)—yielding *Amplexizaphrentites*, *Caninia*, cf. *Gorizdronia*, *Rotiphyllum* and *Zaphrentites*—is difficult to correlate because these long-ranging taxa have a limited use in biostratigraphy. Higgs et al. (2002) recognized the *pretiosus-clavata*-PC Miospore Zone in the same horizon, allowing a correlation with the late Ivorian. Indeed this horizon yields the oldest Carboniferous fauna of the Arabian Plate (Denayer and Hoşgör 2014), as it is often the case with the deposits of the latest Ivorian transgression resting either on older basement or on siliciclastics (Poty 2007a).

Palaeobiogeography

The Late Tournaisian was a time of relatively high sea level allowing good communication between the palaeobiogeographic provinces (Poty 2007a; Somerville 2008; Aretz et al. 2014). The Late Tournaisian coral faunas are consequently widely distributed. *Amygdalophyllum*, *Cyathoclisia*, *Keyserlingophyllum*, *Siphonophyllia*, *Uralinia* are among the commonest genera at this time in the Palaeotethys Ocean, witnessing their ability to colonize tropical and temperate environments (for a more detailed discussion of this adaptability, see Denayer accepted). Hence their utility in palaeobiogeography is limited as is that of *Amplexus*, *Caninia* and *Cyathaxonia*. *Zaphriphyllum*, long considered as typical of North America, being documented in North Africa, South China, the British Isles and now in north-western Turkey, has to be considered as cosmopolitan as well. The absence of *Keyserlingophyllum* and *Siphonophyllia* is presumably a pseudo-absence due to the poor exposure of the strata that could, potentially, yield specimens of these genera. Among the taxa collected in North-western Turkey, *Sychnoelasma* and *Corphalia* are of most interest for palaeobiogeographic point of view since they were described only in the European provinces. *Sychnoelasma* occurs in Western and Eastern Europe. And *Corphalia* occurs only in Western Europe. Occurrences reported from China are both younger (Sepukhovian and 'Middle Carboniferous', Wang 1989, Wang et al. 2010) and the generic attributions are in need of confirmation. *Corphalia* and *Sychnoelasma* are consequently indicative of the Eastern and Western Provinces of Dubatolov and Vassiljuk (1980), Fedorowski (1981) and Sando (1990), covering the eastern (Ural Mountains) and southern margin of Laurussia (British Isles, Northern France, Belgium,

Western Germany, Poland and Donets Basin). Such affinity is already noticed among the Strunian (Latest Devonian) coral association of Zonguldak and Bartın (Denayer, [in press a](#)) and for the Early Viséan (Denayer 2011) and Late Viséan (Denayer, [in press b](#)). The Late Tournaisian—Early Viséan coral assemblages of the Central Taurides (southern Turkey) differs from the European Province by the occurrence of *Kueichouphyllum*. This genus indicates that the Taurides were, at this time, under an Asian influence as were all the Cimmerian blocks (Asian margin of Gondwana). In conclusion, the north-western Turkey and southern Turkey belonged to two distinct provinces, namely the (Western) European of Dubatolov and Vassiljuk (1980) and Sando (1990) and Cimmerian (Denayer accepted).

Conclusions

Contrary to the Viséan corals associations, the rugose corals of the Late Tournaisian of north-western Turkey are not diversified (eleven species, including one new, belonging to ten genera) but they allow the identification of three biozones (RC3, RC4 α and RC4 β 1 of Poty et al. 2006) in the Ivorian (Late Tournaisian) despite the absence of several guide taxa. The widely distributed taxa *Cyathoclisia* and *Uralinia* are present in north-western Turkey. Moreover, the wide distribution of the genus *Zaphriphyllum* in the Palaeotethys Ocean is confirmed. The occurrence of the genera *Corphalia* and *Sychnoelasma* indicates the European affinity of the rugose coral association of north-western Turkey. Differences in composition of the coral associations are between the Zonguldak and Bartın areas results mainly in difference in exposure of the fossiliferous levels.

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