

## Givetian rugose corals of the Schlade Event Bed (Bergisch Gladbach, Germany)

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**Abstract:** In the middle–upper Givetian strata of the Bergisches Land, the Schlade Event Bed is an unusual black mudstone horizon that fouled a sea bottom community made of corals and stromatoporoids. The coral assemblage, here taxonomically described, is dominated by two taxa: *Temnophyllum latum* and *Acanthophyllum vermiculare*. The position of the corals in the sediment and ecological adaptations tend to show that they lived in turbid water, most probably during the deposition of the mud but were not reworked in it as previously suggested.

**Kurzfassung:** In der mittel–ober–givetischen Schichtenfolge des Bergischen Landes ist das Schlade Event Bed ein ungewöhnlicher schwarzer Schlammsteinhorizont, der eine Meeresbodengemeinschaft aus Korallen und Stromatoporoiden enthält. Die hier taxonomisch beschriebene Korallen–Vergesellschaftung wird von zwei Taxa dominiert: *Temnophyllum latum* und *Acanthophyllum vermiculare*. Die Lage der Korallen im Sediment und ihre ökologischen Anpassungen deuten darauf hin, dass sie in trübem Wasser lebten, höchstwahrscheinlich während der Ablagerung des Schlamms, aber nicht darin umgelagert wurden, wie früher angenommen.

**Keywords:** palaeoecology, turbidity, Middle Devonian, Rhenish Massif

**Schlüsselwörter:** Paläoökologie, Trübung, Mitteldevon, Rheinisches Massiv

### Introduction and settings

The Schlade River Valley, some 20 km northeast of Cologne, is a classical locality for the Givetian “Massenkalk” in the Bergisch Gladbach–Paffrath Syncline of the Rhenish Massif (Fig. 1). Historical records of fossils from this locality can be traced through the literature back to the 18<sup>th</sup> century (cf. Jux 1964, 1977) as the Givetian (Middle Devonian) strata yield an abundant well-preserved fauna. The quarries were designated as National Geosite in 2006 in order to preserve this exceptional exposure of a Givetian reef and lagoon. The site covers several abandoned quarries, including the Zimmermann quarry and Grubenfeld quarry that yielded the classical invertebrate fossil fauna that are present in many collections worldwide, including the famous *Stringocephalus* and *Uncites* brachiopods.

Although the Schlade fossils are relatively well known (e.g. gastropods, echinoderms, Bohatý & Herbig 2010, Frýda 2000; bivalves, Rogalla & Amler 2000; stromatoporoids, Krebedünkel 1995; tabulate corals, May & Becker 1996; rugose corals, Schröder 2005), the precise stratigraphy and palaeoenvironmental settings of the succession was poorly known. Bohatý & Herbig (2010) published a detailed

sedimentological and palaeoecological study based on the composite section of the now deteriorated outcrops of the Schlade Valley.

After Bohatý & Herbig (2010) the succession belongs to the Büchel Schichten of middle to late Givetian age (Fig. 1). It starts with coarse-grained limestone with abundant reef debris, suggesting a proximal “fore-reef” environment over-

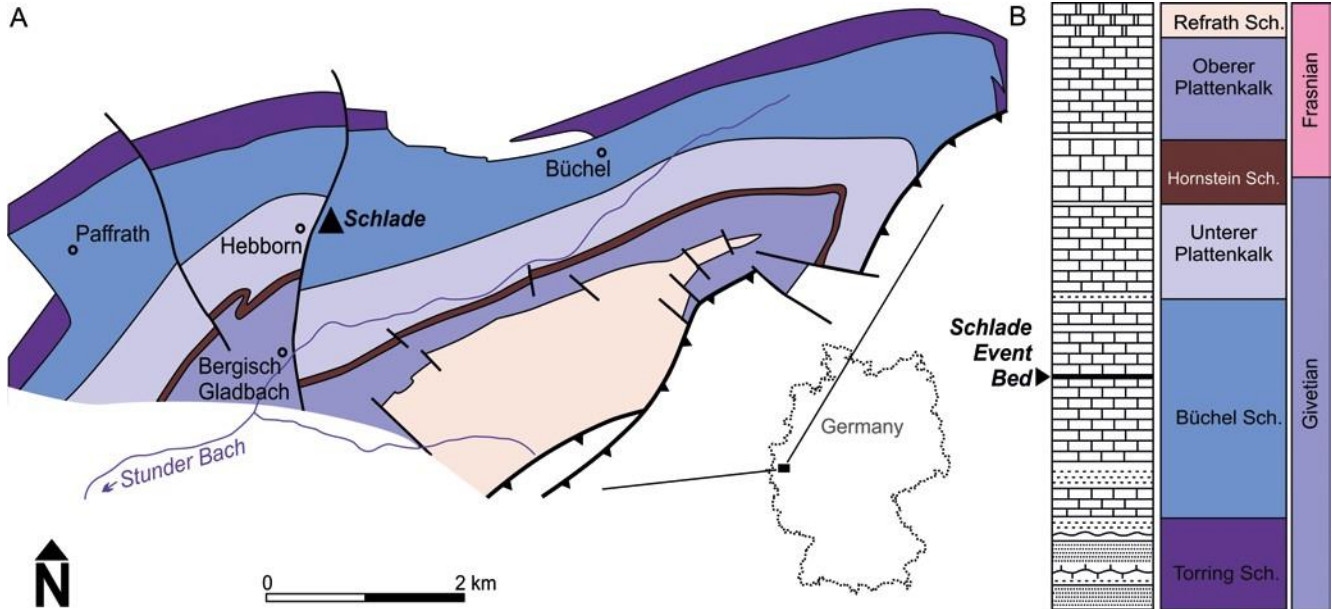
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lain by a stromatoporoid biostrome with mostly massive stromatoporoids and ramose tabulate corals. The biostrome is covered in a coarse-grained bioclastic limestone made of reef and coral debris embedded in a silty matrix and enveloping small globular and columnar stromatoporoids. This 1.8 m unit is topped by c. 1 m of dark grey to black bituminous calcareous shale with sharp lower and upper boundaries. This unusual bed was defined as the Schlade Event Bed by Bohatý & Herbig (2010). Despite its homogeneous aspect, it presents a vertical succession starting with dark shale draping the heads of the stromatoporoids and corals (both tabulate and rugose) that protrude from the underlying bed. The corals described here are from this horizon. Thin fossiliferous laminae occur in the lower part. The fossils are mostly microfossils (foraminifers,

ostracods, sponge spicules, micromorph brachiopods and gastropods) but also disarticulated echinoderms, trilobites and non-calcified macroalgae (not continental plant debris as stated by Bohatý & Herbig 2010). Upwards, the coaly impressions of algae are more abundant and better preserved, reaching up to 10 cm in length and 0.5 cm in width (Fig. 2A). The event bed is overlain by a second biostrome, largely dominated by massive and ramose

tabulate corals with few stromatoporoids and rugose corals. Upwards, accumulations of amphiporid stromatoporoids and fine-grained limestone beds suggest the development of a lagoon. The lagoonal facies passes to a shallow-water reef flat characterised by reef rubble horizons interrupted by marly limestone rich in fossils that are interpreted as reef flat pools. The classical well-preserved Schlade fossils are mostly from these rubble and marl facies.

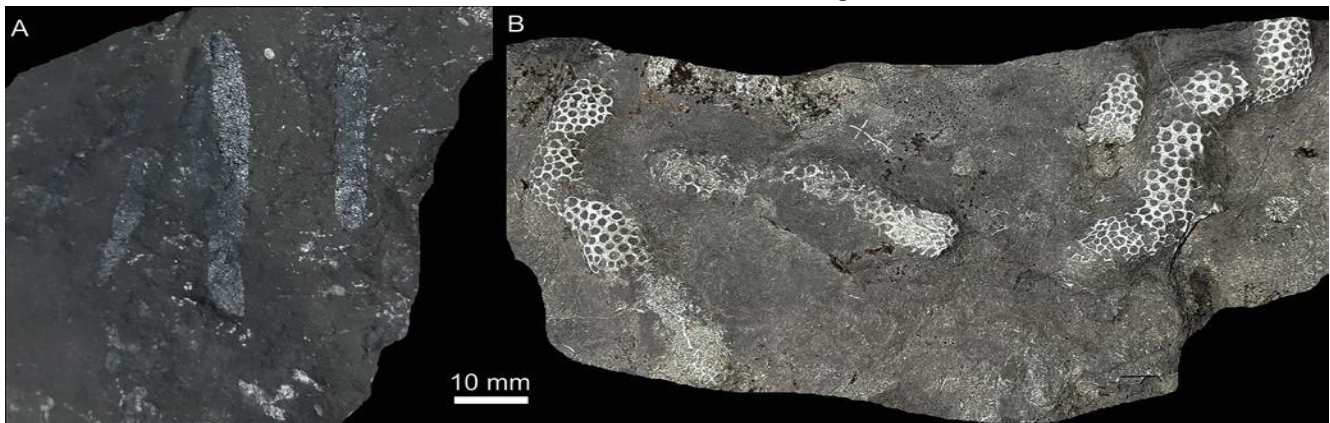


**Fig. 1:** Geological and stratigraphical settings of the Schlade Event Bed. (A) Simplified geological map of the Paffrath-Bergisch Gladbach area (modified from Jux 1964). (B) General stratigraphy of the Givetian and Lower Frasnian of the area (after Kleibrinker 1992; Jux 2008 and Bohatý & Herbig 2010). The studied area is indicated by the triangle. Abbreviation: Sch. – Schichten.

## Material and methods

The present material was collected in 2017 in the Grubenfeld quarry during a field trip led by Hans-Georg Herbig. About 40 specimens were collected in situ from the lower c. 10 cm of the Schlade Event Bed. Contrary to the opinion of Bohatý &

Herbig (2010), the rugose corals are not reworked from the bed below but are in life position, so they lived in the turbid water during the deposition of the mud and were eventually killed by the excessive deposition of the dysoxic mud. Though most of the collected specimens are cylindrical and were lying horizontally on the bottom, several ceratocylindroids were still in erect position, suggesting that they continued to grow for a short time after the mud started to



**Fig. 2:** Macroscopic view of selected fossils from the Schlade Event Bed, Grubenfeld quarry, Bergisch Gladbach. (A) Carbonaceous ribbon corresponding to remains of marine non-carbonate algae. (B) *Thamnopora* sp. branches partly connected.

deposit. Tabulate corals are mostly small (<4 cm) hemispherical alveolite colonies and branches of *Thamnopora* sp. that are almost unbroken (Fig. 2 B), suggesting that they only tilted on the sea floor but were not reworked or transported. The lack of conspicuous erosion corals. In one case, a rugose coral is embedded in a stromatoporoid (Fig. 3F) and displays intergrowth features demonstrating that both organisms grew at the same time before being buried in the mud. The occurrence of attachment structures in the juvenile stages of rugose corals indicates that the larvae settled on hard substrates such as fragments of *Thamnopora* sp. Though not restrictive, this phenomenon is usually observed in muddy or soupy ground where debris (e.g. shells, coral branches) act as an anchoring point for other organisms (Scrutton 1998).

The material was studied both in external shape and in thin sections. All the specimens are deposited in the Animal and Human Palaeontology Collections of the University of Liège (Belgium).

## Systematic palaeontology

### Genus *Acanthophyllum* Dybowski, 1873

**Type species:** *Cyathophyllum heterophyllum* Milne-Edwards & Haime, 1851 from the Middle Devonian of the Eifel Hills (Germany).

**Diagnosis:** See Birenheide (1978).

*Acanthophyllum vermiculare* (Goldfuss, 1826)  
Fig. 3A–G

\* 1826 *Cyathophyllum vermiculare* Goldfuss : 58, pl. 17, fig. 4.

2011 *Acanthophyllum vermiculare* (Goldfuss). – CoenAubert (2011): 37, pl. 2, figs 1–5, pl. 3, fig. 9 [cum. syn.].

2020 *Acanthophyllum vermiculare* (Goldfuss). – Jamart & Denayer (2020): figs 5A–C.

2020 *Acanthophyllum* sp. 1. – Jamart & Denayer (2020): figs. 5G–H.

**Holotype:** Specimen GMB0 198 of the Goldfuss collection. Goldfuss (1826) indicates that his specimen is from the “transitional limestone” of the Eifel Hills. However, Schlüter (1889) considers that the type of preservation of the material is not coherent with an Eifel origin but is more indicative of the Büchel Schichten of the Paffrath Syncline (Bergisches Land, Germany), an opinion also suggested by Gräf (1958) and Schröder (2005). In this case, the present material is constituted of topotypes. The exact type horizon is unknown

suggests that the change of sedimentation from the biostrome to the black marls is not associated with a hiatus. Small branches (0.4 mm in diameter) of tabulate corals also occur. Small (<2 cm thick) stromatoporoids are developed on the walls of rugose corals or on branches of tabulate but only the Schlade Event Bed seems to yield this species (cf. Schröder 2005).

**Material:** Eight specimens (16 transverse and 8 longitudinal sections) from the Schlade Event Bed, Büchel Schichten, Grubenfeld quarry.

**Diagnosis:** *Acanthophyllum* having 34–40 septa of each order at a diameter of 20–35 mm. Septa thin to slightly thickened from base to axis. Dissepiments usually inclined (after Coen-Aubert 1997).

**Description:** Cylindrical solitary coral, 20–26 mm in diameter (7–12 mm for the tabularium), having 29–36 septa of each order. Major septa long, irregular in length, thin or spindle-shaped thickened in the dissepimentarium, except their base that usually remains thin (Fig. 3A). Axial ends commonly rhopaloid (Fig. 3F), twisted. One septum (cardinal?) usually longer. Minor septa long, entering into the tabularium, straight, slightly thinner than the major ones, discontinuous in outer dissepimentarium in some specimens (Fig. 3F). Dissepimentarium wide made of <20 rows of dissepiments, including 0–3 rows of lonsdaleoid dissepiments and/or second-order lonsdaleoid dissepiments (Fig. 3C, F) and up to 20 rows of herringbone and concentric interseptal dissepiments in inner dissepimentarium, one row commonly thickened. Wall 0.5–0.8 mm thick and smooth. In longitudinal section, dissepiments small and globular in periphery, more elongated and inclined towards the tabularium (Fig. 3B). Tabularium incomplete made of concave tabellae and some clinotabellae. Spinose carinae on septa visible in longitudinal section (Fig. 3D).

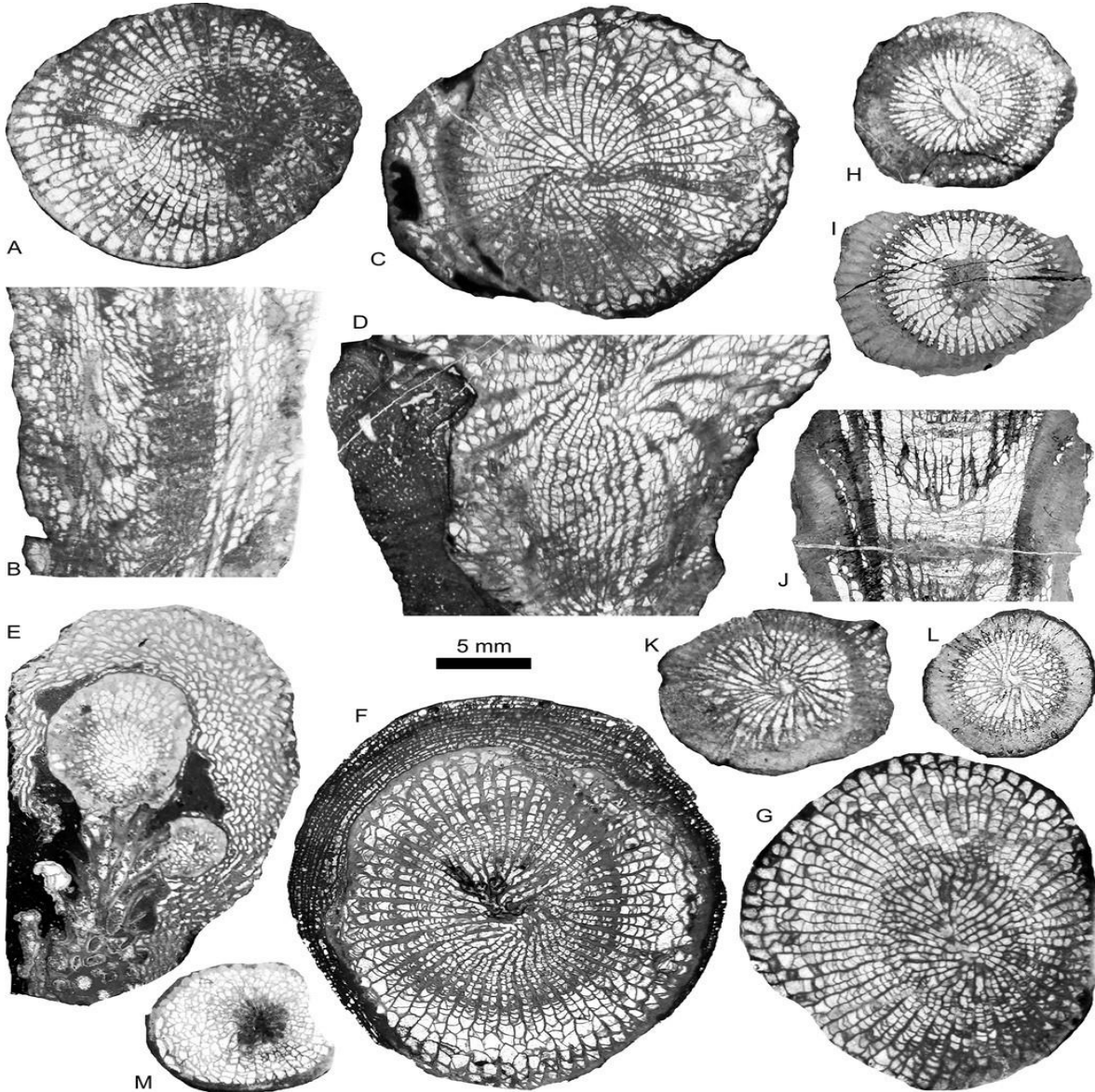
**Discussion:** Coen-Aubert (1997, 2011) indicates that the key features of the species are the relatively narrow dissepimentarium, the inclined dissepiments and the moderate dilatation of the septa, except near the wall where the septa are typically thin. All the characteristics are observed in the present material, but the corals display a broader variability, notably in the development of lonsdaleoid dissepiments. The latter are more developed in larger specimens and might be a characteristic of mature corallites, though a purely ecological effect cannot be ruled out as it is often associated with a growth in turbid water. Such lonsdaleoid dissepiments are commonly observed in rugose corals living in fine-grained sediments (e.g. Late Devonian *Tabulophyllum*, Sorauf 1998; Early Devonian *Papiliophyllum*, Pedder & Murphy 2003; Late Devonian *lowaphyllum*, Sorauf & Pedder 1986). Hubbard (1970) and Sorauf (2007) suggest that such extensive mud-platform in

the calyx, formed by superimposed lonsdaleoid dissepiments were covered in ciliated tissue that acted as mud-sweepers (see plate 1 in Sorauf 2007). Such flat calyx is unknown in *Acanthophyllum*, but lonsdaleoid dissepiments might have served as platforms for mudsweeping tentacles.

One of the specimens displays septal carinae and rhopaloid ends that make it very similar to the coral figured by Schröder (2005: pl. 9, fig. 9) as *Acanthophyllum concavum* (Walther, 1929). The two species *A. concavum* and *A. vermiculare* are very close and often considered as forming a single morphological *vermiculare/concavum* group

(e.g. Birenheide & Lütte 1990; Schröder 2002). Despite its well-developed carinae, this specimen fits in the variability spectrum of the species *A. vermiculare*.

**Distribution:** *Acanthophyllum vermiculare* is one of the youngest species of the genus, ranging from the late Eifelian to the middle-late Givetian of the Eifel Hills (Birenheide 1978), the Sauerland (Schröder 1997), the Ardennes (CoenAubert 1997), the Armorican Massif (Coen-Aubert 2011), the Graz Palaeozoic (Gräf 1958) and North Africa (Schröder & Kazmierczak 1999).



**Fig. 3:** Rugose corals from the Schlade Event Bed, Givetian Büchel Formation, Grubenfeld quarry, Bergisch Gladbach. (A–G) *Acanthophyllum vermiculare* (Goldfuss, 1826). (A–B) Specimen SCH-12, A in transverse section (TS), B in longitudinal section (LS). (C–D) SCH-4, C in TS, D in LS. (E) SCH-13, juvenile specimens attached to a *Thamnopora* branch and overgrown by *Alveolites* sp. (F) SCH-5 in TS. (G) SCH-2 in TS. (H–L) *Temnophyllum latum* Walther, 1929, H: SCH-15 in TS, I–J: SCH-3, I in TS, J in LS, K: SCH-9 in TS, L: SCH-14 in TS. (M) *Grypophyllum* cf. *wedekindi* Middleton, 1959. SCH-10 in TS.

## Genus *Temnophyllum* Walther, 1929

**Type species:** *Temnophyllum latum* Walther, 1929, from the Middle Devonian of the Sauerland (Germany). **Diagnosis:** Solitary coral with septa thickened in the outer dissepimentarium forming a complete or incomplete stereozone. Major septa long, reaching almost the axis but leaving an axial zone free of septa. Dissepimentarium made of several rows of small sub-globose dissepiments inclined towards the axis, nearly vertical in inner dissepimentarium. Tabularium incomplete made of horizontal to concave axial tabellae and declined peripheral tabellae (after Zhen & Jell 1996: 78).

**Discussion:** The genus *Temnophyllum* and its relationships with *Spinophyllum* Wedekind, 1922 and *Alaiophyllum* Gorianov, 1961 were discussed by Zhen & Jell (1996), Coen-Aubert (2002, 2003, 2004) and Schröder (2005). These discussions are not repeated here.

*Temnophyllum latum* (Walther,  
1929) Fig. 3H–L

\* 1929 *Temnophyllum latum* Walther: 123, fig. 14.  
2005 *Temnophyllum latum* Walther. – Schröder (2005): 70, pl. 4, figs 3–9 [cum. syn.].

**Holotype:** Specimen SMF WDKD. 6971–6172 from the Givetian Schwelm Limestone (Oberhonsel Formation) of Deilinghofen (Sauerland, Germany).

**Diagnosis:** Small *Temnophyllum* 12–15 mm in diameter having 26–34 septa of each order. Major septa reaching the axial zone, minor septa half as long as the major ones. Compact and narrow peripheral stereozone (after Schröder 2005).

**Material:** Six specimens (11 transverse and 3 longitudinal sections) from the Schlade Event Bed, Büchel Schichten, Grubenfeld quarry.

**Description:** Cylindrical to scolecoïd solitary coral up to 5 cm in length, 10–13 mm in diameter (7–9 mm for the tabularium), having 26–29 septa of each order. Major septa long but not reaching the axis where they leave an empty zone up to 1.5 mm in diameter (Fig. 3H, L), faintly carinate in the inner tabularium (Fig. 3K). Minor septa half as long as the major ones, entering slightly into the tabularium, contrasting or bent in the cardinal quadrants and straight in the counter quadrants (Fig. 3H, K). All septa strongly thickened in the dissepimentarium, forming a 2 mm wide stereozone extending from the wall to the dissepimentarium-tabularium boundary (Fig. 3H–L). Dissepimentarium made of 2–4 rows of concentric and angulo-concentric interseptal dissepiments, usually drowned into the stereozone.

In longitudinal section, dissepiments irregular in size and shape, almost vertically disposed (Fig. 3J). Tabularium incomplete made of flat axial tabellae and 2–3 rows of periaxial tabellae inclined towards the axis.

**Discussion:** The present material has the typical characteristics of *Temnophyllum latum* Walther, 1929: small size, long major septa and short minor septa, and a compact stereozone. However, it differs from the type material by its slightly shorter major septa that usually leave an empty space at the axis. This feature is variable in the present material, the septa being longer and commonly connected in sections cut above a tabula but withdrawn below the next tabula. The contraclinal or bent minor septa is a feature not described in any species of *Temnophyllum*, however, Schröder's (2005: pl. 4, fig. 5) illustrations clearly show this characteristic. *Temnophyllum tenue* Walther, 1929 has a similar size and is supposed to differ by the development of carinae on the axial part of the septa. However, this species, only known by its holotype, could seemingly be included in the intraspecific variation of *T. latum* that also occasionally develops some axial carinae (e.g. Schröder 2005: pl. 4, figs. 5a, 6a). *T. astrictum* Walther, 1929 is also similar in size and irregular development of carinae but is also characterised by a more complex and wider dissepimentarium. *T. majus* Walther, 1929 and *T. walteri* Yoh, 1937 are both larger (diameter >15 mm).

**Distribution:** The species occurs in the middle–late Givetian Büchel Schichten and Oberhonsel Formation of the Bergisches Land.

## Genus *Grypophyllum* Wedekind, 1922

**Type species:** *Cyathophyllum denckmanni* Wedekind, 1922 from the Middle Devonian of Bergisch Gladbach (Bergisches Land, Germany).

**Diagnosis:** See Birenheide (1978).

*Grypophyllum* cf. *wedekindi* (Middelton,  
1959) Fig. 3M

**Material:** A single specimen (2 transverse and 1 longitudinal sections) from the Schlade Event Bed, Büchel Schichten, Grubenfeld quarry.

**Description:** Small solitary cylindrical coral 9 mm in diameter (4 mm for the tabularium), having 22 septa of each order. Major septa long, reaching the axis, sinuous, some joined. Minor septa short, discontinuous in dissepimentarium. Dissepimentarium wide, consisting of up to 15 rows

of irregular dissepiments (first and second order lonsdaleoid dissepiments, herringbone dissepiments and concentric interseptal dissepiments). Wall smooth, up to 1 mm thick.

Carinae visible on the septa in longitudinal section.

**Discussion:** After its small diameter and limited development of the minor septa, this single specimen seems to be a juvenile of *Grypophyllum wedekindi* Middleton, 1959. However, it displays a few lonsdaleoid dissepiments that are uncommon in that species. Again, this element could be of ecological origin as in *Acanthophyllum vermiculare*.

## Conclusions

The rugose corals presented here were in situ in the dark marly horizon corresponding to the Schlade Event Bed and were not reworked at the base of this horizon as supposed by Bohatý & Herbig (2010). Arguments for their contemporaneity with these fine-grained sediments are the occurrence of attachment structures (Fig. 3D–E) – suggesting a soft ground – and possibly the development of lonsdaleoid dissepiments – suggesting the need to repel mud from the calyx. Rugose corals are known to be better than stromatoporoids and tabulate corals at coping with turbid water and fine-grained

sediment, probably because of their larger corallites and their tentacular apparatus, more efficient in cleaning the mud. Episodic influxes of sediment that buried the organisms could explain why so few epibionts (e.g. annelids, bryozoans, microbes) colonised the coral epitheca (see Zatoń et al. 2018). However, in the present case, the anoxia associated with the burst of soupy sediment is probably the cause of the demise of the corals.

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I was very lucky to participate in field trips with Hans-Georg Herbig and to share his enthusiastic pleasure of looking at sedimentary successions, collecting fossils and gathering arguments to understand palaeoenvironments. He introduced me to the Middle Devonian of the Bergisches Land and was happy to entrust me with the study of this material. Hence, this short contribution is a tribute to what Hans-Georg did best: tell geological and geologist's stories. I am grateful to Błażej Berkowski and Bernhard Hubmann for their reviews of the manuscript and to Thomas Wotte and Michael Amler, who invited me to contribute to this homage volume.

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