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Clypeina helvetica Morellet and Morellet, 1918, revisited. A Priabonian (Late Eocene) dasycladalean alga from the Diablerets Nappe of the Helvetic Alps, southwestern Switzerland

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Abstract The dasycladale *Clypeina helvetica* was described and illustrated with six drawings by Morellet and Morellet (Bull Soc Géol Fr 4^{o} ser 18:102–105, 1918) from the "Bartonian" of the Helvetic Zone of southwestern Switzerland. Since then, *C. helvetica* has not been reported again neither from Switzerland nor from any other locality. Abundant material sampled from the Priabonian Diablerets Member of the Sanetsch Formation in the type area Lapis de Tsanfleuron permits a more detailed description of the species including biometric data and thin-section illustrations. *C. helvetica* is validated by the designation of a lectotype to serve as nomenclatural type.

Keywords Dasycladales · Eocene · Taxonomy · Helvetic Alps · Switzerland

Introduction

In 1918, Lucien and Jean Morellet described a new species of dasycladalean green alga in an Eocene fragment of rock from Lapis (Lapies) de Tsanfleuron (Diablerets Nappe, western Swiss Alps). The rock belongs to the fossiliferous beds traditionally known as "Couches à Cérithes" and is characterized by a floatstone texture with the presence of abundant verticils of this dasycladalean alga and shells of potamidid gastropods. They named this alga *Clypeina helvetica*.

Since then, almost 100 years have passed and *C. helvetica* still is known only from its type locality and original description, which includes an illustration with six drawings (Morellet and Morellet 1918) (Fig. 1). For this reason, Deloffre and Génot (1982) stated that *C. helvetica* is "relatively unknown", "poorly quoted and illustrated", and that "the validity of this species is dubious". Based on material collected at the type locality for the study of its Late Eocene transgressive rocks (Bover-Arnal et al. 2011), the present paper aims to amend these deficiencies by providing a detailed description of *C. helvetica*, including biometric data and photographic illustrations, as well as to formalize the species validity.

According to the available bibliography, dasycladales suffered a drastic reduction of species diversity during the Eocene after a peak in the Late Paleocene with 105 species in the Thanetian (Barattolo 2002). From 52 species in the Early Eocene (Ypresian) the number became reduced to only eight species in the Priabonian (Barattolo 2002). Therefore, this study is of significance in that it provides a data set of a poorly known species, which flourished in a time period characterized by a reduced Dasycladaceae taxonomic diversity.

Geological setting

The Tsanfleuron-Sanetsch area in southwestern Switzerland (Fig. 2) is part of the Alpine Helvetic zone and is composed of a nappe pile that consists of Mesozoic and Paleogene rocks. Lower Cretaceous karstified limestones

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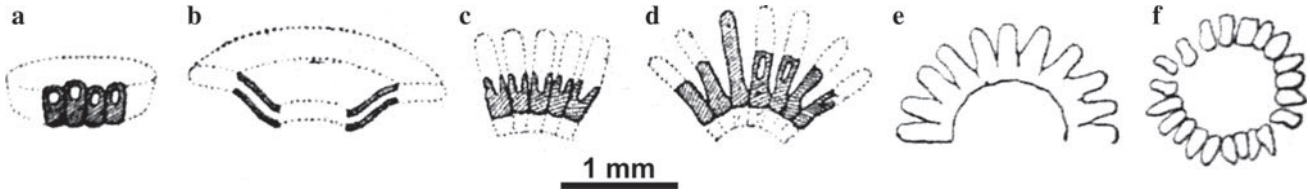

Fig. 1 Original drawings (**a**–**f**) of *Clypeina helvetica* by Morellet and Morellet (1918, fig. 2)

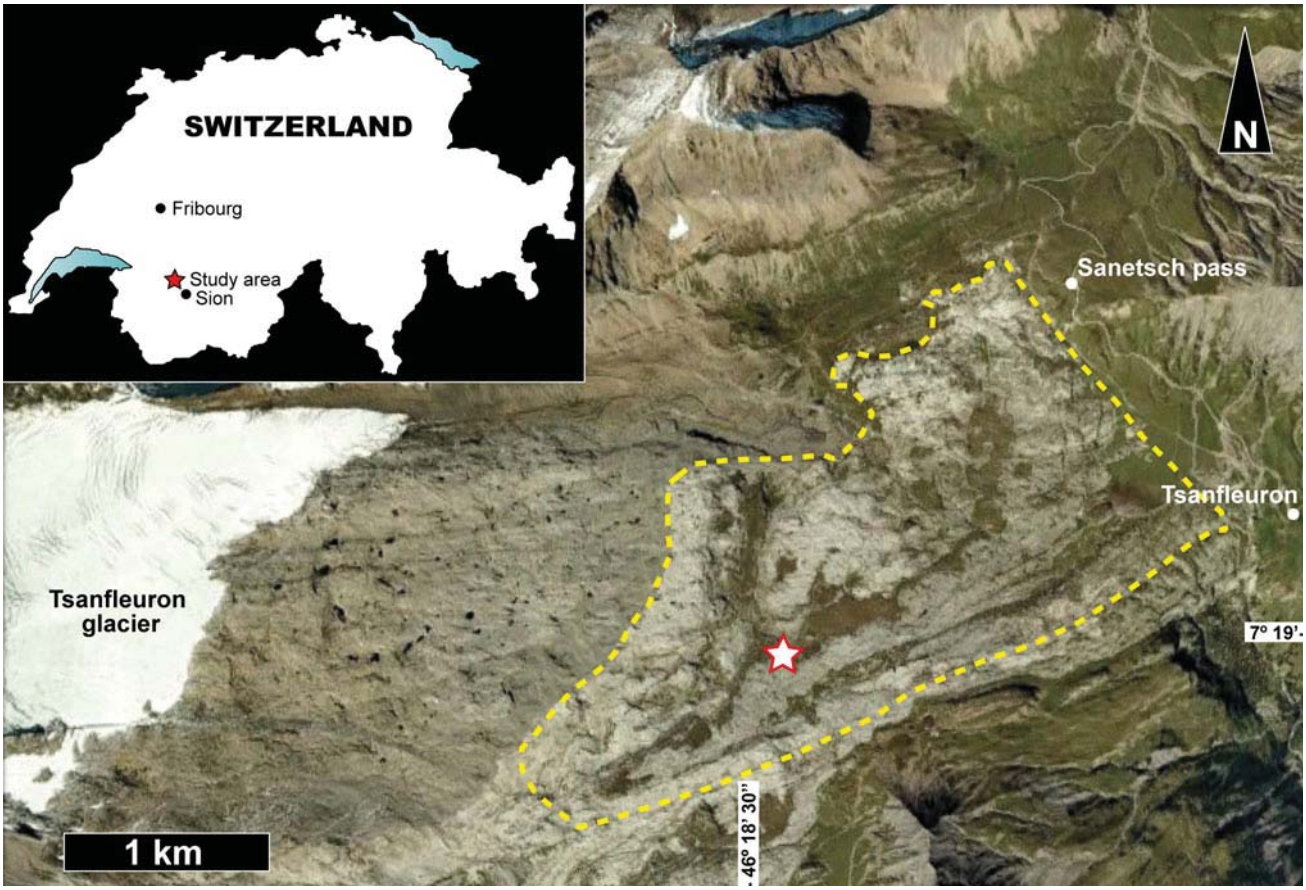

Fig. 2 Area where the Diablerets Mb. (Early Priabonian; Sanetsch Fm.), which contains the levels with prolific *Clypeina helvetica*, crops out (*dashed yellow line*). The *star* indicates the position of the logged section illustrated in Fig. 4

of the Schrattenkalk Formation are overlain by transgressive Paleogene (Eocene to Oligocene) strata. The transgressive rocks comprise (roughly summarized from base to top): lacustrine, brackish, and shallow-marine limestones with marly interbeds, cross-bedded sandstones, limestones with nummulitids, marls with *Globigerina*, and flysch deposits (Menkveld-Gfeller 1994). The informal "Couches à Cerithes" of the type area are today assigned to the Diablerets Member of the Sanetsch Formation. Based on the nummulites occurring in the overlying strata, the Diablerets Member is Early Priabonian in age (Menkveld-Gfeller 1994). Dasycladalean algae, including the dispersed verticillar disks of *C. helvetica*, are common constituents in the terrigenous-influenced, partly brackish limestones of the Diablerets Member resting upon a karstified paleorelief of the Schrattenkalk Formation (Bover-Arnal et al. 2011) (Figs. 3, 4).

Systematic paleontology

Division Chlorophyta Reichenbach, 1834
Order Dasycladales Pascher, 1931
Family Acetabulariaceae (Endlicher) Hauck, 1885
Tribus Clypeineae Elliott, 1968
Genus *Clypeina* (Michelin) Bassoullet et al. 1978
Clypeina helvetica Morellet and Morellet, 1918
Figs. 5, 6, 7, 8

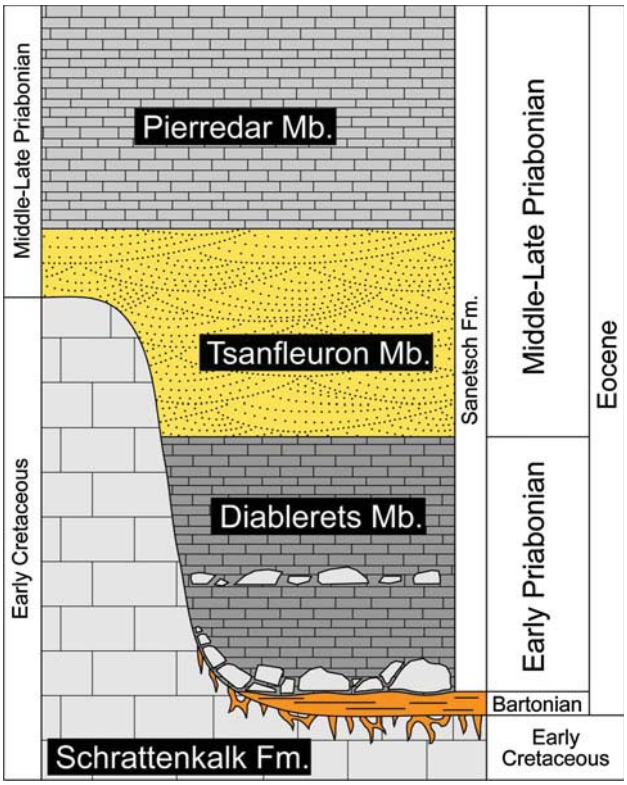

Fig. 3 Stratigraphy of Cretaceous to Eocene rocks at the Lapis de Tsanfleuron. Modified from Bover-Arnal et al. (2011). The ages of the deposits are taken from Herb (1988), Weidmann et al. (1991), Menkveld-Gfeller (1993, 1994, 1995), and Linder (2005)

*1918 *Clypeina helvetica* n. sp.—Morellet and Morellet: 105, fig. 2a–f

Lectotype versus holotype

Morellet and Morellet (1918) did not designate a holotype. Their description was based on a rock sample provided by Maurice Lugeon indicated as no. 11289 deposited at the Geological Museum in Lausanne (Switzerland). The sample is still stored in the collection of the museum and is illustrated in Fig. 5a, b. From this rock sample full of algal debris, the authors made six drawings, stating that the color contrast between the algal remains and the host rock is too small for providing good-quality photographs. From the original drawings, the transverse view illustrated as Fig. 2F in Morellet and Morellet (1918) and refigured here in Fig. 1f is designated as a lectotype (articles 9.10, 9.11 I.C.B.N.; McNeill et al. 2006).

Type locality

The rock sample on which the description of *C. helvetica* is based was collected from the "Couches à Cérithes des lapiez de Zanfleuron" (Morellet and Morellet 1918). These

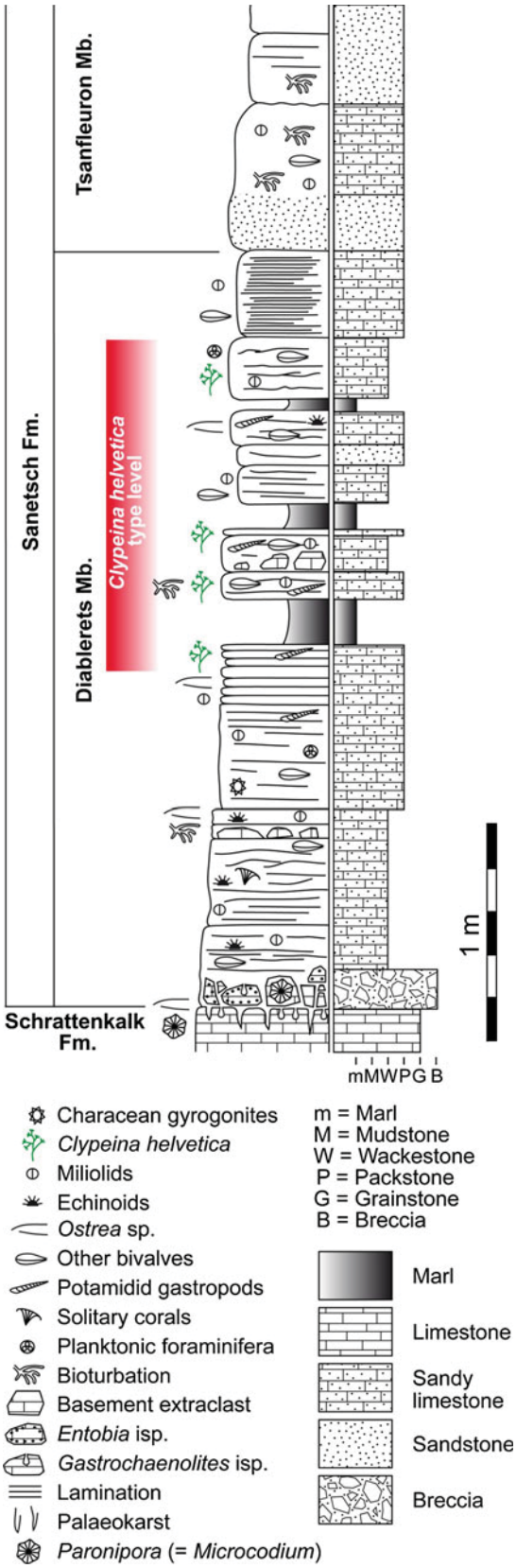

Fig. 4 Log of the Diablerets Member showing the lithostratigraphic context for the type material of *Clypeina helvetica* (see Fig. 2 for position of the log)

◀ **Fig. 5** *Clypeina helvetica* Morellet and Morellet. **a** Rock sample (collected by M. Lugeon in 1906) from the Lapis de Tsanfleuron area, on which the original description and drawings of Morellet and Morellet (1918) were based. Note that this sample was described as "totally intermingled with *Clypeina* debris" (Morellet and Morellet 1918, p. 105: "absolument pétri de debris d′un *Clypeina*"). The *black rectangle* marks the detailed view shown in **b**. Sample no. 11289, Musée Géologique Lausanne, Couches à Cérithes (=Diablerets Member of Menkveld-Gfeller 1994). **b** Detail from **a** showing the dispersed verticils of *Clypeina helvetica*. **c** Rock surface with abundant dispersed whorls of *Clypeina helvetica* (from Bover-Arnal et al. 2011, fig. 13c). Diablerets Member, Lapis de Tsanfleuron, Early Priabonian

are the only data available about the type locality. The location certainly corresponds to the Lower Priabonian succession of the Sanetsch Formation, from the Lapis de Tsanfleuron that has been described by Weidmann et al. (1991), Menkveld-Gfeller (1993, 1994), and Bover-Arnal et al. (2011). This succession crops out in an area of $\sim$12 km^2 (Fig. 2), where *Clypeina helvetica* occurs with potamidid gastropods and pelecypods in sandy marly limestones (Figs. 3, 4; see also Fig. 6 in Menkveld-Gfeller 1994). The Priabonian outcrops of the Lapis de Tsanfleuron are situated within a small valley running in a SW direction, (Coordinates: 46°18′N/7°16′E, sheet No. 1286, St-Léonard, 1:25,000, Swisstopo).

Type level

Light-brown to dark grey wacke- to floatstones containing siliciclastic material (Fig. 6). Shells of tiny ostracodes and miliolids are the dominating microfauna. Besides *Clypeina helvetica*, potamidid gastropods and cardiid bivalves constitute the dominant macrobiota. Also present are rare and fine debris of corallinacean algae, remains of crustaceans, individual tests of the larger miliolid *Orbitolites* sp. (Fig. 6b) and lithoclasts from the Lower Cretaceous Schrattenkalk Formation, which contain *Paronipora* (*Microcodium*) within fissures. From the studied thin-sections, the following trend was observed: the more gastropod shells the less *Clypeina* remains, with the two end-members of pure gastropod or pure *Clypeina* limestones.

Material

The thin-sections of this study are housed at the Naturhistorisches Museum of the Burgergemeinde Bern, section Earth Sciences, material Ursula Menkveld-Gfeller (numbers: SP 139, 139-1, 139 D-2), and material Telm Bover-Arnal (LT 03).

Diagnosis

In the original description, no diagnosis was given. It is provided here as follows: Large-sized *Clypeina* (diameter

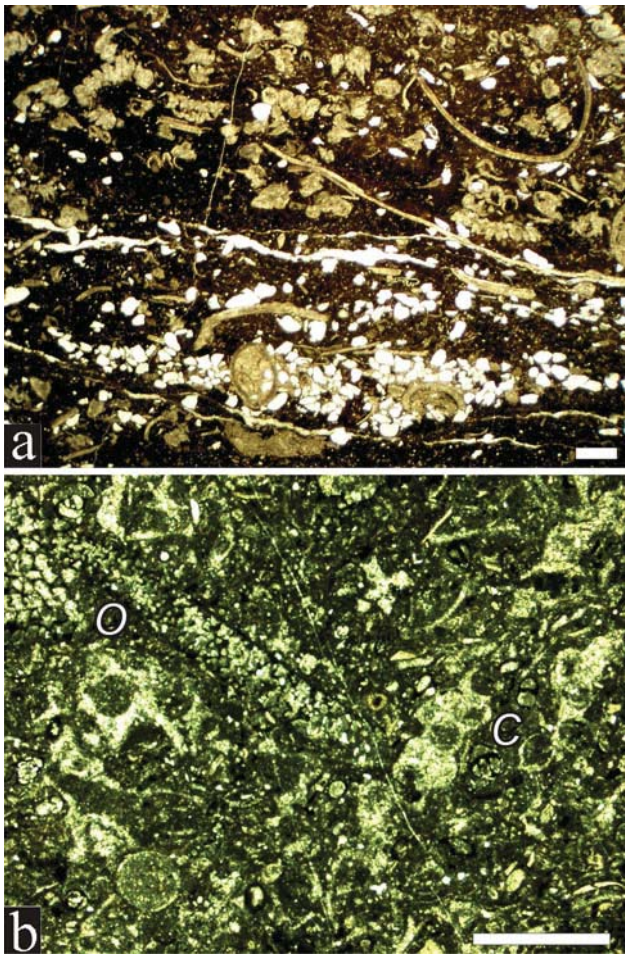

Fig. 6 Microfacies. **a** Wackestone with quartz grains arranged in layers (*lower part of the photograph*), scattered pelecypod shells and abundant remains of *Clypeina helvetica* Morellet and Morellet (*upper part*). Thin-section SP 139 D-2. **b** Wackestone with debris of *Clypeina helvetica* Morellet and Morellet (*C*), and miliolids including a large test of *Orbitolites* sp. (*O*). Thin-section LT 03. Diablerets Member, Lapis de Tsanfleuron, Early Priabonian. *Scale bars* 1 mm

up to 2.63 mm) only known as isolated shallow saucer-shaped articles (whorls) consisting of numerous (up to 32) laterals. The laterals are fused only at their proximal parts (max. 1/4 of their length), thus giving to the whorl an outline that resembles a flower. The distal ends of the pores are not calcified and were presumably open. The original individual sheath calcification comprises a thin outer microcrystalline and a thick inner layer consisting of yellowish, radial-fibrous calcite. Whorls may also be recrystallized to light sparry calcite.

Description Rather large *Clypeina* species (D: up to 2.63 mm) being preserved only as scattered individual whorls (Fig. 5c). Two or more successive whorls were not observed as obviously the stipe was only poorly calcified. The whorls are saucer-shaped and exhibit a short portion arranged perpendicular to slightly inclined to the main stem then bending upwards before again bending slightly

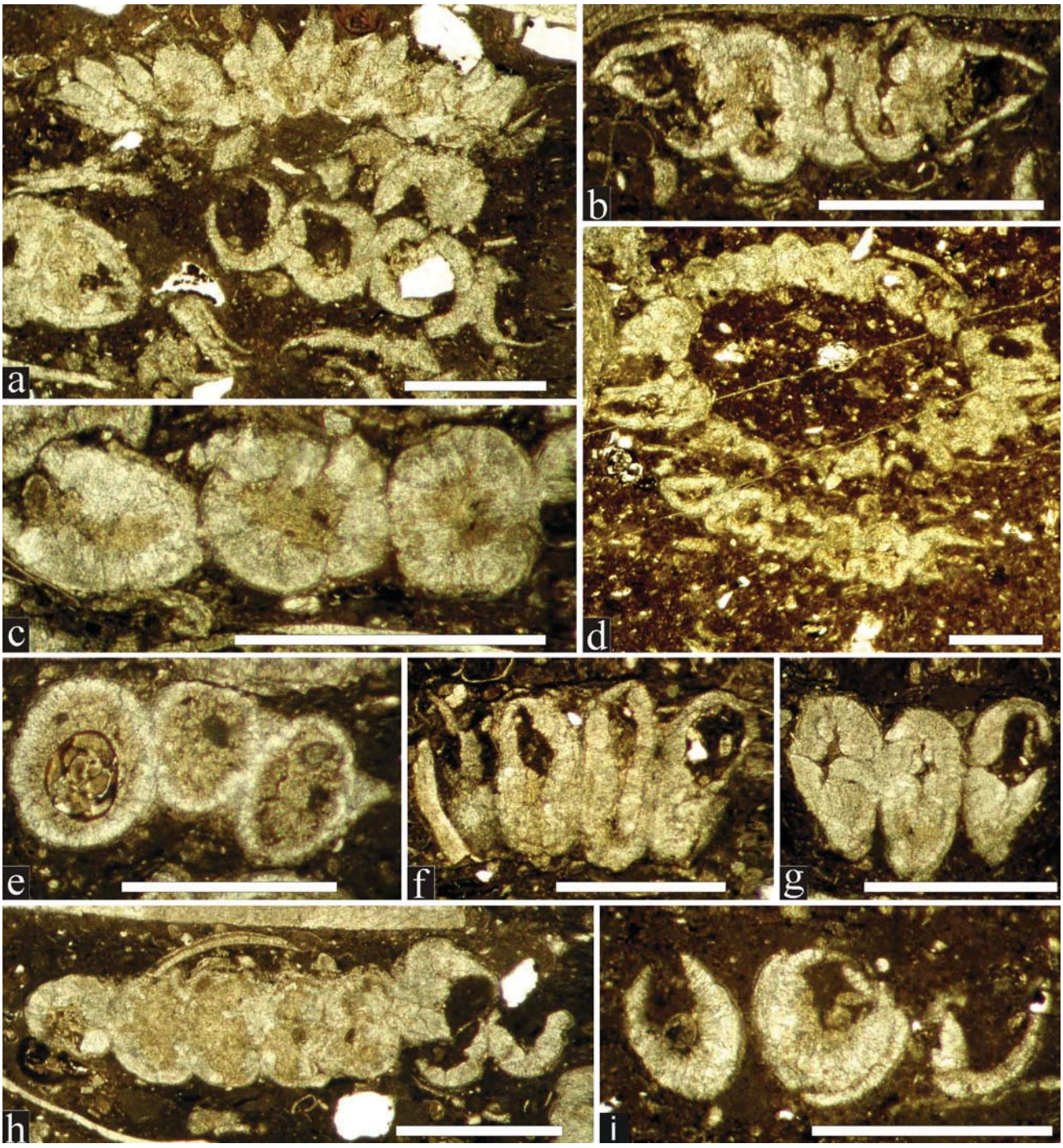

Fig. 7 *Clypeina helvetica* Morellet and Morellet exhibiting radial-fibrous calcitic preservation. **a** Oblique (*above*) and tangential section (*below*). **b** Deep longitudinal-tangential section of a comparably small specimen. **c, e, i** Tangential sections of three laterals loose (**c, e**) or without contact (**i**) to each other. Note the occupation of the original pore space by cement encapsuling bioclasts (miliolid foraminifer in **e**). **d** Oblique transverse section. **f–g** Tangential sections cutting the inclined portion of the whorl with the pores in the upper part. **h** Tangential section. Diablerets Member, Lapis de Tsanfleuron, Early Priabonian. **a**, **c**, **g**: Thin-section SP 139 D-2; **b**, **d**, **h–i**: thin-section SP 139-1; **e** thin-section SP 139. *Scale bars* 0.5 mm

backwards in a plane forming the shape of a shallow saucer (Fig. 1b). The numerous primary laterals (w: 21–32) are only fused at their base and then become individualized during growth, giving the whorl a flower-shaped outline in transverse view (Fig. 1f). Due to the distally uncalcified laterals and open pores, the axial cavity mostly accounts for more than the preserved outer whorl diameter (d/D mean: 0.67). The laterals widen only moderately

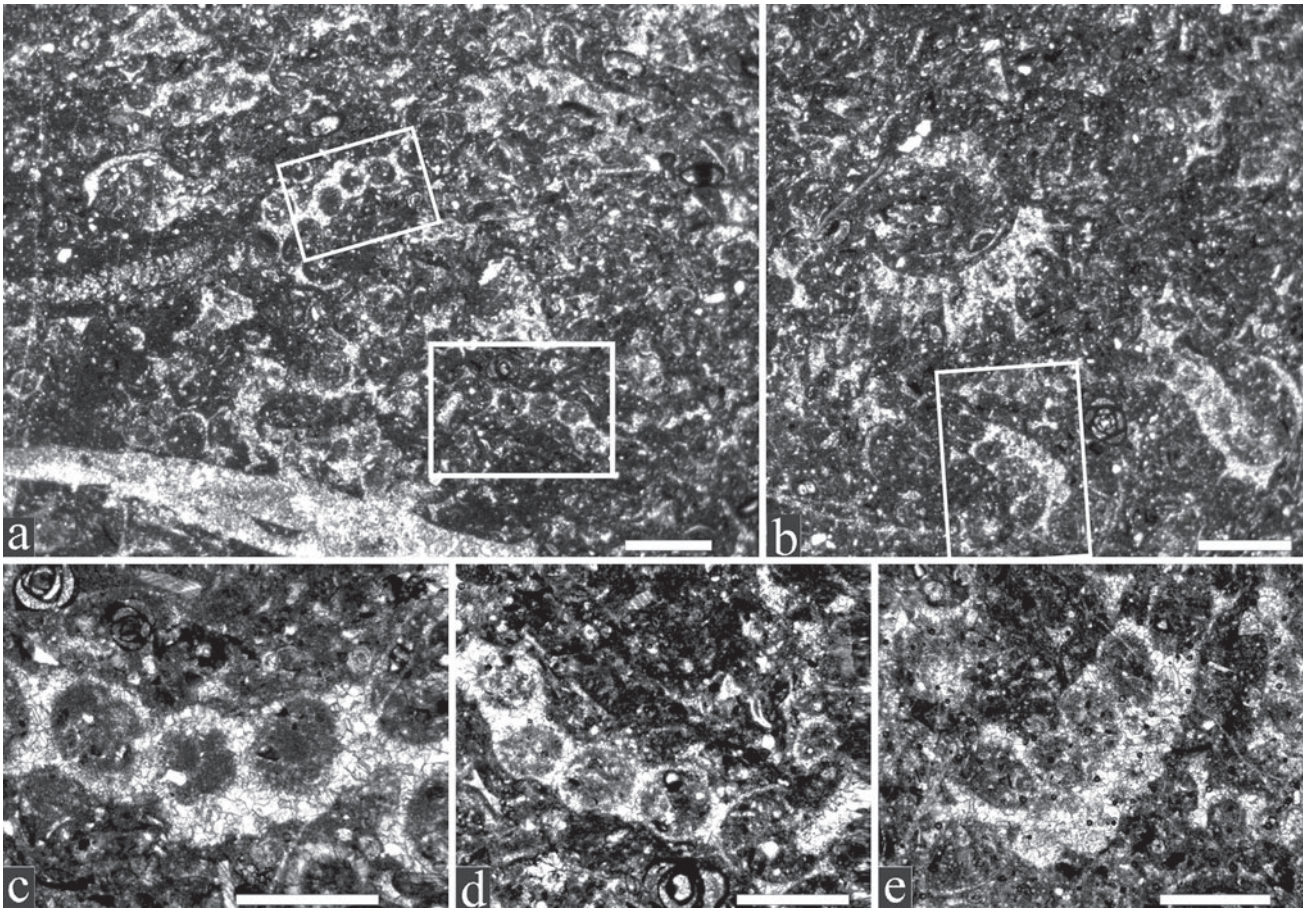

Fig. 8 **a–b** Wackestone with abundant *Clypeina helvetica* Morellet and Morellet exhibiting recrystallized whorls made up of sparry calcite (*white rectangles* mark the details shown in **c–e**). **c–d** Transverse sections of laterals with subspherical pores. **e** Subvertical section of a whorl proximal to the main stem. Diablerets Member, Lapis de Tsanfleuron, Early Priabonian. Thin-section LT 03. *Scale bars* 1 mm for a, b, 0.5 mm for c, e

throughout the length (phloiophorous type) or remain more or less constant in width (akrophorous type). Their diameter ranges from ∼0.12 to ∼0.35 mm. Depending on the plane of the section, the transverse sections of the laterals maybe rounded to ovoid (Fig. 7c, e, i). Sections through the bent parts display elongated-ovoid morphologies with the pore opening situated at the upper part, as if the laterals would be compressed perpendicularly to the plane of the whorl (Figs. 1a, 7f, g). Two different calcification patterns of the whorls can be distinguished referring to the assumed original and to a transformed recrystallized type (Figs. 7, 8). The assumed original calcification is composed of a thin outer membrane (thickness ∼10 to 20 μm) enveloping each lateral individually (Fig. 7). This membrane appears either slightly brownish and microgranular, or it is composed of tiny, parallel radially arranged crystal fibers. The boundary between the outer membrane and the inner zone is marked by a thin micritic layer (thickness about 2 μm). The inner zone is made up of hyaline fibrous calcite (thickness ∼0.12 to 0.35 mm). The central part may be filled with the micritic matrix (Fig. 7f, i) or completely by cement, locally completely enveloping infiltrated bioclasts (Fig. 7e). Reproductive structures have not been observed inside the laterals. The second type of calcification is represented by uniform and colorless sparry calcite (Fig. 8). Both types, however, have never been observed to occur together within the same sample.

Dimensions

See Table 1.

Remarks

Taking into account our new data, it can be stated that the species description of Morellet and Morellet (1918) based on dispersed verticils on a weathered rock sample (Fig. 5a, b) was very accurate. The new findings from the type area add biometric data and characteristics of the wall structure, allowing further and better comparisons to other *Clypeina* species. Different calcification patterns of fossil dasycladalean algae were summarized by Conrad and Varol

Table 1 Dimensions of *Clypeina helvetica* Morellet and Morellet (in mm, except for the d/D ratio)

	D	*d*	d/D	*w*
1	1.78	0.84	0.47	
2	1.92	1.32	0.68	
3	2.3	1.6	0.69	26
4	1.97	1.32	0.67	28
5	2.2	1.52	0.69	
6	2.4	1.52	0.63	
7	2.3	1.62	0.7	30
8	1.6	1.01	0.63	
9	2.2	1.37	0.62	
10	1.92	1.56	0.81	
11	2.43	1.5	0.78	
12	1.32	0.87	0.66	
13	2.53	1.42	0.56	26
14	1.72	1.01	0.59	
15	2.12	1.32	0.62	
16	2.02	1.22	0.6	
17	1.7	1.17	0.69	
18	2.63	1.92	0.73	
19	2.53	1.52	0.6	32
20	1.72	1.14	0.66	
21	2.63	1.62	0.61	
22	1.92	1.1	0.57	
23	2.63	1.52	0.58	
24	1.82	1.11	0.61	
25	1.92	1.36	0.71	
26	1.72	1.09	0.63	
27	1.52	0.96	0.63	
28	2.53	1.52	0.6	
29	2.53	1.36	0.53	
30	1.72	1.01	0.59	
31	1.32	0.9	0.68	
32	1.7	1.02	0.6	21
33	2.46	1.45	0.59	24
34	2.3	1.4	0.61	22
min.	1.32	0.84	0.47	21
max.	2.63	1.92	0.78	32
Mean	2.05	1.31	0.64	

D outer diameter of calcified part of the whorl; *d* inner diameter of whorl; *w* number of laterals per whorl

(1990). Accordingly, the type evidenced for *C. helvetica* belongs to the group with "hyaline sheaths, possibly of intracellular origin". It consists of a thin external microcrystalline layer representing the organic membrane and a comparably thick inner layer of hyaline (occasionally yellowish) radial-fibrous calcite of supposed intracellular origin. Each lateral is thereby surrounded by individual sheaths (see De Castro 1997, p. 161, for further details).

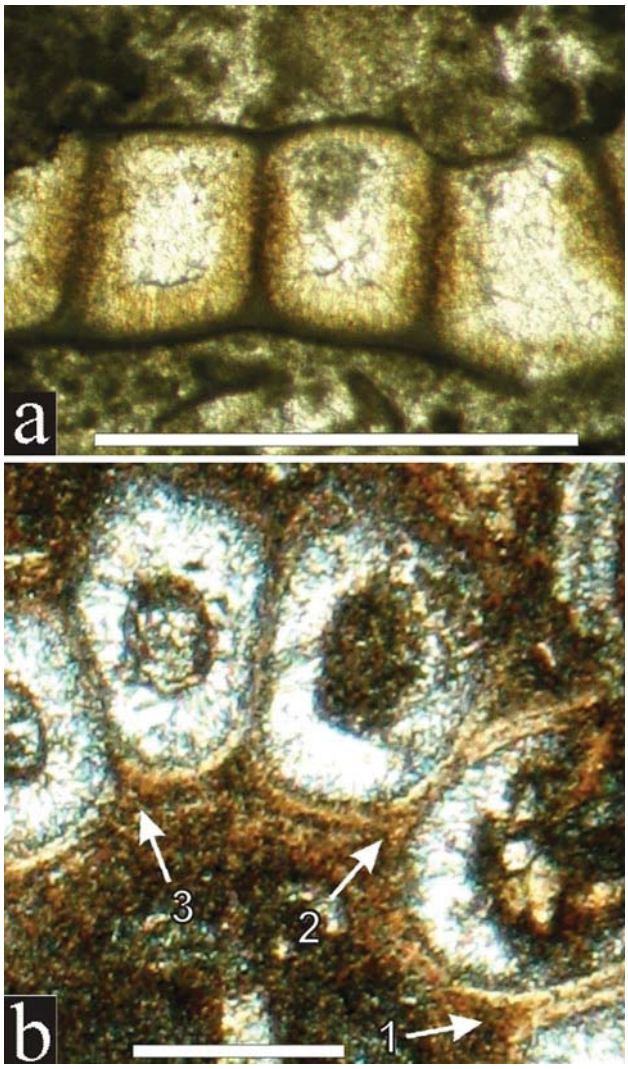

Fig. 9 Examples of the calcification pattern of the "*Clypeina jurassica* group". **a** *C. jurassica* Favre, Kimmeridgian of Albania. **b** *C.*? *teakolarae* Radoičić, Jurkovšek and Jovanović, Early Eocene (Cuisian) of Slovenia. Lateral wall well individualized (*arrow* 1, 3) to slightly fused (*arrow* 2) (leg R. Radoičić). *Scale bars* 1 mm

Examples of this group of species are the Late Kimmeridgian to Late Berriasian *Clypeina jurassica* Favre (Fig. 9a), the Late Berriasian *Clypeina isabellae* Masse, Bucur, Virgone, and Delmasso, or the Early Eocene *Clypeina teakolarae* Radoičić, Jurkovšek and Jovanović (Fig. 9b). Given that *Clypeina jurassica* is the most widespread and well-known species of all these, Radoičić et al. (2011) referred to them to as the "*Clypeina jurassica* group". With respect to these examples, one could get the impression that this calcification pattern is restricted to the genus *Clypeina*, which is not the case. *Clypeina*? *teakolarae*, for instance, exhibits spaced double verticils (= twin whorls sensu Radoičić et al. 2011), which are incompatible with the spaced single whorls displayed by *Clypeina* (e.g., Génot 2009, fig. 2). Depending on the connection of the

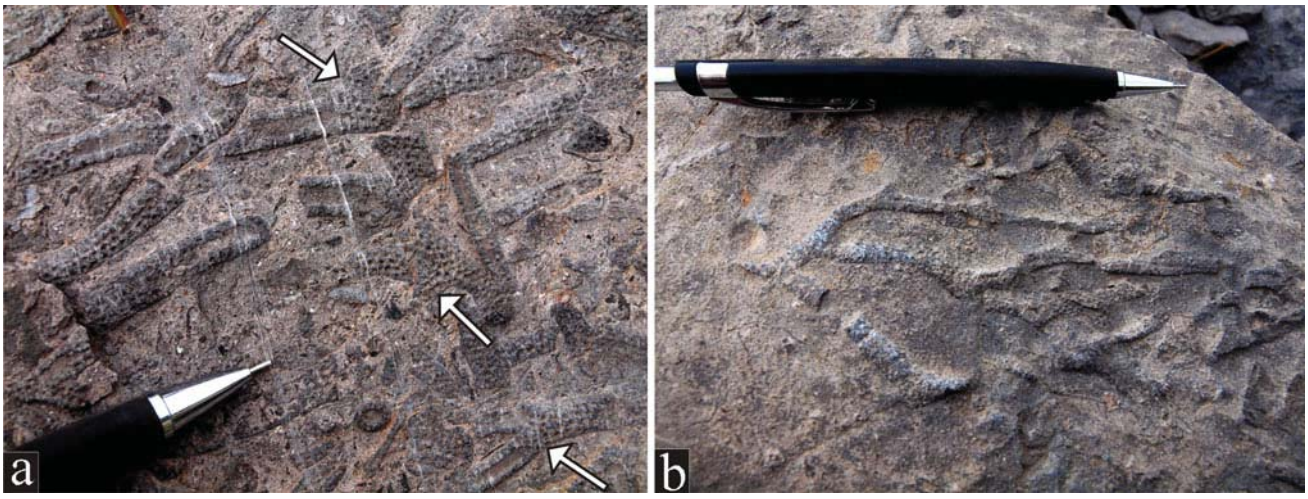

Fig. 10 **a** Monospecific assemblage of an unknown branching (*arrows*) dasycladalean alga. **b** Tree-like branching of unknown dasycladalean alga (from Bover-Arnal et al. 2011, fig. 13d). Diablerets Member, Lapis de Tsanfleuron, Early Priabonian

laterals to the main axis, it should be transferred to *Milanovicella* Granier and Berthou or *Praturlonella* Barattolo (see Granier and Berthou 1994 for details). The mentioned taxa also have in common that the laterals are open at their tips. According to Conrad and Varol (1990, p. 206), this feature suggests an in vivo intracellular mineralization process following the release of fertile ampullae. In exceptional cases, the fertile ampullae are preserved enclosed in this intracellular calcification as evidenced from e.g., *C. jurassica* and *C. isabellae* (Schlagintweit et al. 2009). Some of the dasycladaleans exhibiting this calcification type were adapted to brackish or polyhaline habitats (Conrad and Varol 1990), an observation that can be ascertained also for the Diablerets Member with *Clypeina helvetica*. Concerning the two documented types of preservation, the homogeneous sparry calcite undoubtedly results from the transformation of the radial fibrous type. The sparry calcite type usually results from the dissolution of the former aragonite, the mineral that makes up the skeleton of extant Dasycladales (e.g., Berger and Kaever 1992), and the infilling of the mould with calcite cement. Obviously, the two rock samples we studied underwent different diagenetic pathways, with details so far poorly understood. De Castro (1997, pl. 2) illustrated several states of preservation in *Clypeina jurassica*. Diagenesis can lead to variable infillings of the pores by cement or in an advanced stage to a "crystalline mosaic that uniformly fill(s) the area occupied by both the pores and the associated individual sheats". This recrystallization pattern resembles that of the dissolution of a primary aragonitic skeleton. In summary, *C. helvetica* represents the so far youngest record of a dasycladalean species with this peculiar type of radial-fibrous preservation (see also Granier 2012). Unfortunately, an approach to the problem using modern counterparts is not possible given that the last appearance of the genus *Clypeina* is in the Early Oligocene (Rupelian) (Barattolo 2002).

Besides *C. helvetica*, there are some other species of dasycladales occurring in the Diablerets Member typically forming monospecific assemblages (Fig. 10). Mass occurrences of individual species indicate that the paleoenvironmental setting was obviously structured and exhibiting several microhabitats (Bover-Arnal et al. 2011). The now-confirmed Early Priabonian age of the type level of *C. helvetica* (Menkveld-Gfeller 1994) and the additional findings of other, so far not described, dasycladalean taxa provide further information about the Eocene decline of dasycladaleans. According to Barattolo (2002), 30 species in the Barthonian contrast with only eight species in the Priabonian. The generic extinction, however, reached a relative maximum in the Bartonian, so that—according to Barattolo (2002)—a new period of crisis took place triggered by so far unknown reasons. A refining of the database will be possible by a future thorough systematic study and inventory of the dasycladaleans from the Diablerets Member.

Comparisons

Morellet and Morellet (1918) compared *C. helvetica* with the two allied species, *C. digitata* (Parker and Jones) from the Lutetian of France and *C. marginiporella* Michelin (type species; from the Rupelian of France), both known only as isolated whorls (see also Génot 2009; Génot and Granier 2011). Above all, *C. helvetica* differs from these two species by its distinctly larger whorls bearing a large number of laterals (Fig. 11). In addition to the biometric data, there are also some differences of the morphology of

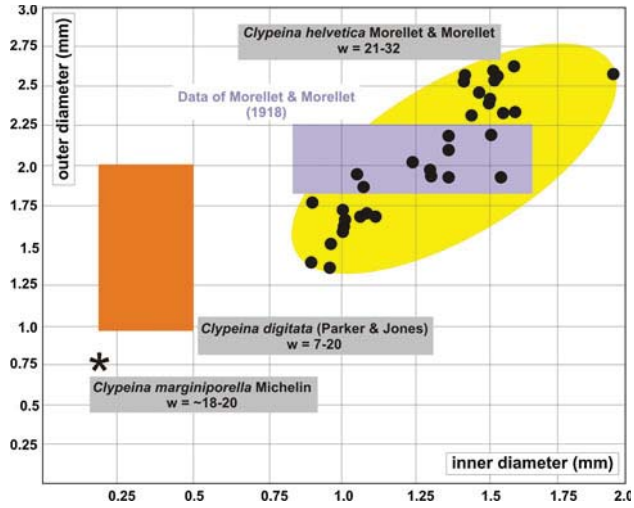

Fig. 11 Outer diameter of calcified part of the whorl (D) against inner diameter (d) (in mm) of *Clypeina helvetica* Morellet and Morellet compared with some other Paleogene *Clypeina* species that are only known from their isolated whorls: *Clypeina marginiporella* Michelin (type species; Rupelian of France) and *Clypeina digitata* (Parker and Jones) (Lutetian of France). Data used are from Deloffre and Génot (1982). The data sets of *C. digitata* and *C. helvetica* (from Morellet and Morellet 1918) are represented by *rectangles* as only ranges of both parameters (d, D) were given in the original description. *w* number of laterals per whorl

the whorls (or umbels in Morellet and Morellet 1918). For *C. helvetica*, "these are less flat than those of *C. digitata*, but also less infundibuliform than those of *C. marginiporella*" (Morellet and Morellet 1918). Concerning the calcification pattern documented for *C. helvetica*, it is not known whether it is similar to the one in the other two species.

Stratigraphic distribution

In the original work of Morellet and Morellet (1918), the age was indicated as "Bartonian à facies littoral (fide Boussac)". This statement most probably refers to Boussac (1912), who worked on the Eocene sediments of the Diablerets region. It should be mentioned that in previous times the Bartonian was considered a superstage comprising the whole Late Eocene. The tripartite subdivision of the Bartonian (Early, Middle, and Late) was, for example, used by Deloffre and Génot (1982) for their stratigraphic range charts of Paleogene Dasycladales, placing *C. helvetica* within the whole Bartonian up to the Eocene/Oligocene boundary. In the Paleogene standard scale (e.g., Cavelier and Pomerol 1976), the Bartonian is placed between the Lutetian (both Middle Eocene) and the Priabonian (=Late Eocene). According to Menkveld-Gfeller (1994), the Diablerets Member containing *Clypeina helvetica* is Early Priabonian in age based on nummulitid foraminifera encountered in the Pierredar Member. Therefore, the so-far-assumed occurrence in the Bartonian (see range chart in Barattolo 2002) must be revised. Due to the supposed facies sensitivity of *C. helvetica*, it is unlikely that it occurs in the deeper-water facies types (e.g., nummulitid limestones) that overlie the Diablerets Member. Consequently, it can be assumed that in the type-area, *C. helvetica* is restricted to the Early Priabonian shallow-lagoonal facies.

Conclusions

Clypeina helvetica is a valid species. So far its occurrence is restricted to the Early Priabonian Diablerets Member of the Sanetsch Formation, which crops out in the Lapis de Tsanfleuron (Diablerets Nappe; western Swiss Alps). In other areas of the Diablerets Nappe, or in other localities in southwestern Switzerland (e.g., Morcles Nappe) and in France (e.g., Chaînes Subalpines) where the Diablerets Member is exposed, the possible occurrence of *Clypeina helvetica* has to be checked. The documentation of this Dasycladale is of significance in that it provides a data set of a poorly known species, which flourished in a time interval marked by a reduced Dasycladaceae taxonomic diversity with only eight species documented so far.

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