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LATEST JURASSIC - EARLY CRETACEOUS DASYCLADALEAN ALGAE (CHLOROPHYTA) FROM THE MORAND DRILLING AT MONTRICHER (CANTON OF VAUD, SWITZERLAND)

Bruno Granier[1], Bernard Clavel[2], Jean Charollais[3] & MarcWeidmann[4]

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Abstract More than 25 species of Dasycladales are identified in the Berriasian – Hauterivian cored interval of a borehole in the Swiss Jura Mountains. With some reservation, it is proposed to transfer the species *Macroporella praturloni* to the genus *Triploporella*. The combination of the occurrence of some algae with that of some benthic foraminifers confirms the existing biostratigraphic framework. The existence of these algae documents Valanginian-lower Barremian photozoan carbonate production in contrast to some geochemical models that predict it did not exist.

Keywords: Algae, dasycladales, Urgonian, Cretaceous, photozoan, heterozoan.

INTRODUCTION

Relatively rich assemblages of calcareous algae, mostly Dasycladalean green algae, are found in uppermost Jurassic and Lower Cretaceous strata. In shallow-water environments they provide complementary information to that derived from the benthic foraminifers to date these facies. The case studied is a drill hole core near Montricher (Fig. 1), a Swiss locality not far from Éclépens (less than 20 km eastward), particularly known for controversial datings of its Lower Cretaceous section (see discussions in Conrad *et al.*, 2012, and Charollais *et al.*, 2013).

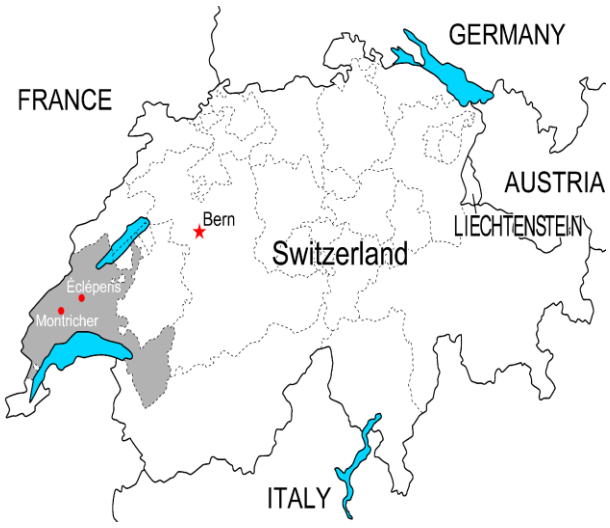

Fig. 1 Location map. Montricher and Éclépens are two localities at the foot of the Swiss Jura mountains.

GEOLOGICAL SETTING

The Morand drill hole, geographic coordinates x:520,025 y:162,180 altitude 665 m, 46°36'11.8"N 6°23'57.9"E (Google coordinates: 46.603478, 6.399386), was initially bored in 1968 to help characterizing the hydrogeologic conditions and later geothermic settings of the Municipality of Montricher (Mornod, 1969, unpublished; Burger & Gohran, 1986; Wilhelm *et al.*, 2003; Bussard *et al.*, 2004; Bussard, 2005), which belongs the District of Morges, Canton of Vaud, Switzerland. It was fully cored and after cutting nearly 37 meters of Quaternary moraines (Mornod, 1969, unpublished; Looser & Davit, 1993; Wilhelm *et al.*, 2003) it penetrated Lower Cretaceous strata and ended in uppermost Jurassic strata at a depth of nearly 400 meters (Wilhelm *et al.*, 2003).

To date published geological investigations on these Mesozoic series, which were subdivided on the basis of lithostratigraphy (Fig. 2), dealt merely with clay minerals (Persoz & Remane, 1976; Persoz, 1982) ; Strasser (1986) presented a detailed lithologic log of the interval 319-329 m that he referred to “Purbeck limestones” and that we ascribe to Pierre Châtel Formation. According to Wilhelm *et al.* (2003), who used an unformal classification, the cores cut Urgonian facies from 37 to 117 m, then "Hauterivian" strata down to 215 m, "Valanginian" strata down to 327m, Purbeckian facies and "Portlandian" strata down to bottom hole. We adopted a discrete classification (Charollais *et al.*, 2008) that follows:

- from 37.20 to 92.42 m, the "Urgonien blanc" *auct.* (white Urgonian). The assemblage of large benthic foraminifers identified by one of us (B.C., unpublished) includes: *Cribellopsis elongata* (Dieni *et al.*),

[1] Department of Ecology and Evolutionary Biology, The University of Kansas, 1200 Sunnyside Avenue, Lawrence, Kansas 66045, USA (bgranier@ku.edu)
[2] 24, ch. des Champs d’Amot, 74140 Messery, France (b.clavel1@orange.fr)
[3] Département de Géologie et de Paléontologie, Sciences de la Terre et de l¹Environnement, 13, r. des Maraîchers, 1211 Genève 4, Switzerland (jdcharollais@bluewin.ch)
[4] 3, sentier du Molard, 1805 Jongny, Switzerland (weidmann-dutoit@bluewin.ch)

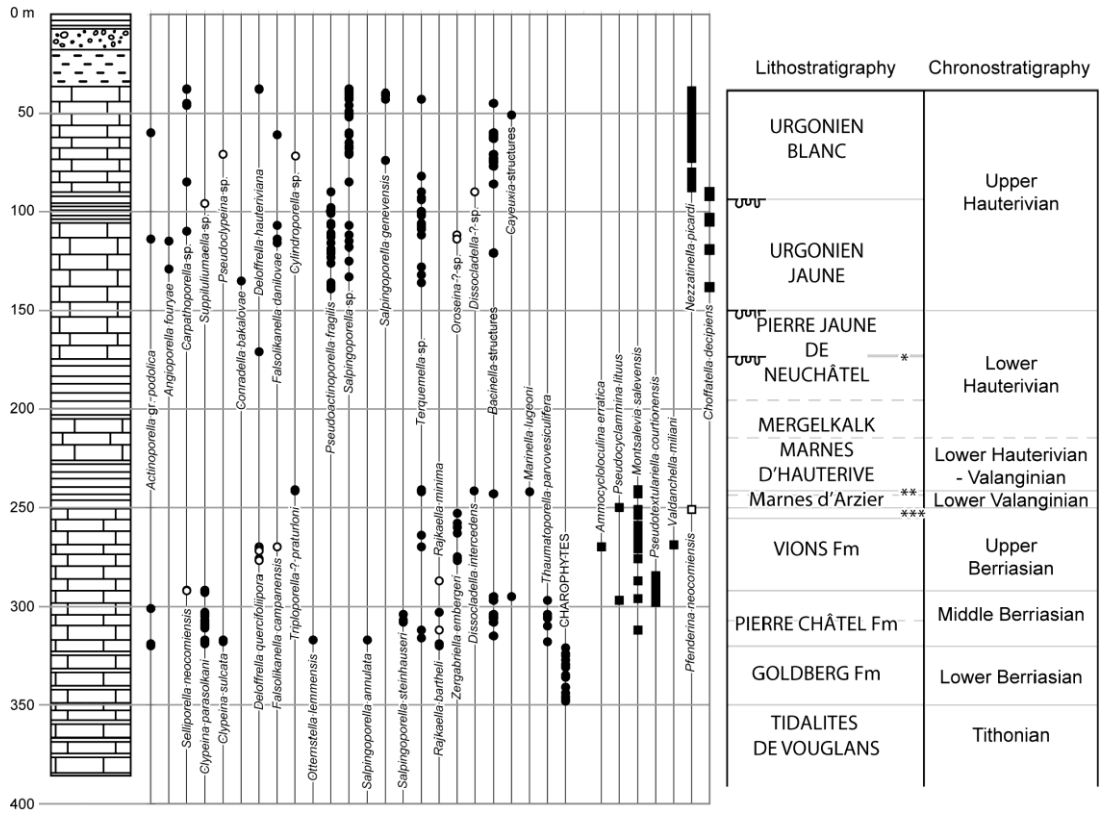

Fig. 2 The occurrences of the Dasycladales, few other algae and foraminifers are plotted on the lithostratigraphic log of the Morand drilling (redrawn and modified from Wilhelm *et al.*, 2003, p. 130). Caption: *: "Marnes d'Uttins", **: "Calcaires roux", ***: Chambotte Fm

Dictyorbitolina carthusiana Schroeder *et al.*, *Eopalorbitolina pertenuis* (Foury), *Falsurgonina vanneauae* Clavel *et al.*, *Montseciella glanensis* (Foury), *Orbitolinopsis debelmasi* Moullade & Thieuloy, *Paleodictyoconus beckerae* (Clavel *et al.*), *Pal. cuvillieri* (Foury), *Paracoskinolina hispanica* Peybernès, *Par.* ? *jourdanensis* (Foury & Moullade), *Par. maynci* (Chevalier), *Par.* cf. *sunnilandensis* (Maync), *Praedictyorbitolina busnardoi* Schroeder *et al.*, *Praed. claveli* Schroeder, *Urgonina alpillensis* (Foury), *Valserina broennimanni* Schroeder & Conrad, and *V. primitiva* Schroeder *et al.*; it should be highlighted that *Palorbitolina lenticularis* (Blumenbach), an Urgonian species characteristic of the late Early Barremian to the Bedoulian times, is not recorded. This assemblage points to an interval mostly time-equivalent to the Balearis and Ohmi ammonite zones (Clavel *et al.*, 2007, 2010, 2013). Common foraminifers in this facies are miliolids, *Nezzatinella picardi* (Henson) and *Coscinoconus* ("*Trocholina*") sp. whereas *Choffatella decipiens* Schlumberger is restricted to the basal part of the interval, which corresponds to a flooding event. At 92.42 m a bored hardground marks the lower boundary of this unit. In the Éclépens section, it is thinner (eroded at this top) but again ascribed a Late Hauterivian age (Conrad *et al.*, 2012; Charollais *et al.*, 2013);

- from 92.42 to 149.30 m, the "Urgonien jaune" *auct.* (yellow Urgonian), which includes oolitic facies with small-sized ooids. The assemblage of large benthic foraminifers (B.C., unpublished) is less diversified with, *Eopalorbitolina pertenuis*, *Paleodictyoconus beckerae*, *Pal. cuvillieri*, and *Praedictyorbitolina busnardoi* Schroeder *et al.*, and *Praed. claveli*. It points to an interval mostly time-equivalent to the Ligatus ammonite Zone (Clavel *et al.*, 2010). A new flooding event is detected at levels 102.10-105.82 m with another acme of *Choffatella decipiens*. At 149.30 m a bored hardground marks the lower boundary of the Urgonian. In the Éclépens section, this unit is more than 50 m thick and is also ascribed a Late Hauterivian age (Conrad *et al.*, 2012; Charollais *et al.*, 2013);
- from 149.30 to 195.00 m, the "Pierre jaune" *auct.* (yellow Stone), is divided into two parts, upper and lower "Pierre jaune", separated by the "Marnes d'Uttins" *auct.* (Uttins Marls) that span a very short interval between 172.15 and a bored hardground at 172.45 m. The whole unit is referred to the Lower Hauterivian (Charollais *et al.*, 2008);
- from 195.00 to 216.40 m, the "Mergelkalk Zone" *auct.* (marly Limestones) is also referred to the Lower Hauterivian (Charollais *et al.*, 2008);
- from 216.40 to 240.90 m, the "Marnes d'Hauterive" *auct.* (Hauterive Marls) include the transition from the Valanginian to the Lower Hauterivian (Charollais *et al.*, 2008). Skeletal components of the lower "Pierre jaune", "Mergelkalk Zone" and "Marnes d'Hauterive" consist dominantly of echinoderm, serpulid and bryozoan bioclasts, commonly partly glauconitized (glauconite occurs in the organic porous network);
- from 240.90 to 243.15 m, the "Calcaires roux" *auct.* (red Limestones). The first occurrence (downhole) of the

foraminifer *Montsalevia salevensis* (Charollais *et al.*) is in sample 240.90;

- from 243.15 to 249.50 m, the "Marnes d'Arzier" *auct.* (Arzier Marls) mark the *Pertransiens* transgression (Charollais *et al.*, 2008). Both the "Calcaires roux" and the "Marnes d'Arzier" are ascribed an Early Valanginian age (Charollais *et al.*, 2008);
- from 249.50 to 254.40 m, the Lower Chambotte Formation is referred to the uppermost Berriasian (Charollais *et al.*, 2008). The unique record of *Pfenderina neocomiensis* (Pfender) is in sample 251 and the last occurrence (downhole) of the foraminifer *Pseudocyclammina lituus* (Yokohama) is in sample 250;
- from 254.40 to 291.73 m, the Vions Formation, including "Unité supérieure gréseuse", is referred to the Upper Berriasian (Charollais *et al.*, 2008). The unique record of *Valdanchella miliani* (Schroeder) and that of *Ammocycloloculina erratica* (Joukowsky & Favre) are in samples 269 and 270 respectively;
- from 291.73 to 320.65 m, the Pierre Châtel Formation. From 306.80 to 316.75 m, the unit is oolithic (see Strasser, 1986: Fig. 2, which covers the interval 319-329 m). The last occurrence (downhole) of the foraminifer *Montsalevia salevensis* (Charollais *et al.*) is in sample 312 and this unit is ascribed a Middle Berriasian age (Charollais *et al.*, 2008);
- from 320.65 to 348.97 m, the Goldberg Formation displays the so-called Purbeckian facies with common Charophytes stems (Fig. 4c-e) and oogonia (Fig. 4f) and is referred to the Lower Berriasian (Charollais *et al.*, 2008), but possibly includes uppermost Tithonian strata;
- from 348.97 to 388.10 m downward, the "Tidalites de Vouglans" are referred to the Tithonian. They consist mainly of laminated mudstone, peloidal facies commonly recrystallized (with a mosaic of large poecilitic calcite crystals engolfing several peloids each), locally brecciated. No visible microfossils, except for rare *Favreina* (at level 357 and 359, for instance).

SYSTEMATIC PALEOPHYCOLOGY (B.G.)

In the following chapter we list most of the Dasycladalean algae found while analyzing petrographic thin sections. Although we found other algae (*Marinella lugeoni* Pfender and *Thaumatoporella parvovesiculifera* (Raineri)) and microbial-related structures (*Bacinella* and *Cayeuxia*), we do not consider them in this paleophycological evaluation.

Phylum Chlorophyta Pascher
Class Dasycladophyceae Hoek *et al.*
Order Dasycladales Pascher

Cretaceous Dasycladales are all verticillated, *i.e.*, their laterals are arranged in a spoke-like fashion along the algal main axis; there are no representatives of the Family Seletonnellaceae (Korde) with laterals randomly set along the main axis.

Famíly Bornetellaceae Granier & Bucur *in* Granier *et al.*

The characteristic of the representatives of this family is to have their reproductive organs sited on the side of the primaries (*i.e.*, on the side of the first order of laterals). This feature was termed the goniosporate type by Granier and Bucur (Granier *et al.*, 2013a, 2013b). We assume that the organogenus *Terquemella* Munier-Chalmas *ex* L. & J. Morellet, which refers to isolated reproductive organs consisting of groups of cysts (Fig. 5a-b), corresponds to skeletal remains of large Bornetellacean algae. Terquemellas are part of all algal assemblages.

Famíly Dasycladaceae Kützing

The characteristic of the representatives of this family is to have their reproductive organs sited at the end of the laterals, either the primaries in primitive genera or higher orders in modern genera; this feature is called the choristosporate type.

Genus *Cymopolia* Lamouroux

In the Upper Hauterivian "Urgonien jaune", we found few poorly preserved remains (Fig. 6n) that can be referred either to a *Cymopolia* Lamouroux or a *Neomeris* Lamouroux.

Family Diploporaceae (Pia)

The representatives of this family have their laterals set in verticillated tufts.

Genus *Falsolikanella* Granier

The genus was initially introduced by Granier (1987a) based on *Likanella campanensis* Azéma & Jaffrezo, *nom. nud.* Later additions, *e.g.*, *Falsolikanella danilovae* (Radoičić *ex* Barattolo) by Granier *et al.* (2000), have strengthened the importance of this genus.

Falsolikanella campanensis Azéma & Jaffrezo *ex* Granier
(Fig. 6d)

This species is part of dasycladalean algae that get mineralized with calcite instead of aragonite (Granier, 2012). It is identified in the Vions Formation.

Falsolikanella danilovae (Radoičić *ex* Barattolo)
(Fig. 3g-h; Fig. 7h)

It is known as a typical Urgonian species; however, it is lacking in uppermost Barremian and Bedoulian strata (Clavel *et al.*, 2007, 2013). Here we find it in both the "Urgonien jaune" and the "Urgonien blanc".

Genus *Selliporella* (Sartoni & Crescenti)
Selliporella neocomiensis (Radoičić)
(Fig. 3f)

This species, also known as *Diplopora johnsoni* Praturlon, is commonly referred to the Tithonian-Berriasian interval. Younger occurrences (Hauterivian) are probably erroneous dating (Granier & Deloffre, 1993; Bucur & Săsăran, 2003). The unique specimen was found in the transition between the Vions and Pierre Châtel formations.

The organogenus *Carpathoporella* Dragastan, 1995, possibly refers to skeletal remains very similar to isolated calcified laterals of Selliporellas; these bioclasts might be broken pieces of a discrete species. According to Schlagintweit and Gawlick (2009), this form refers to

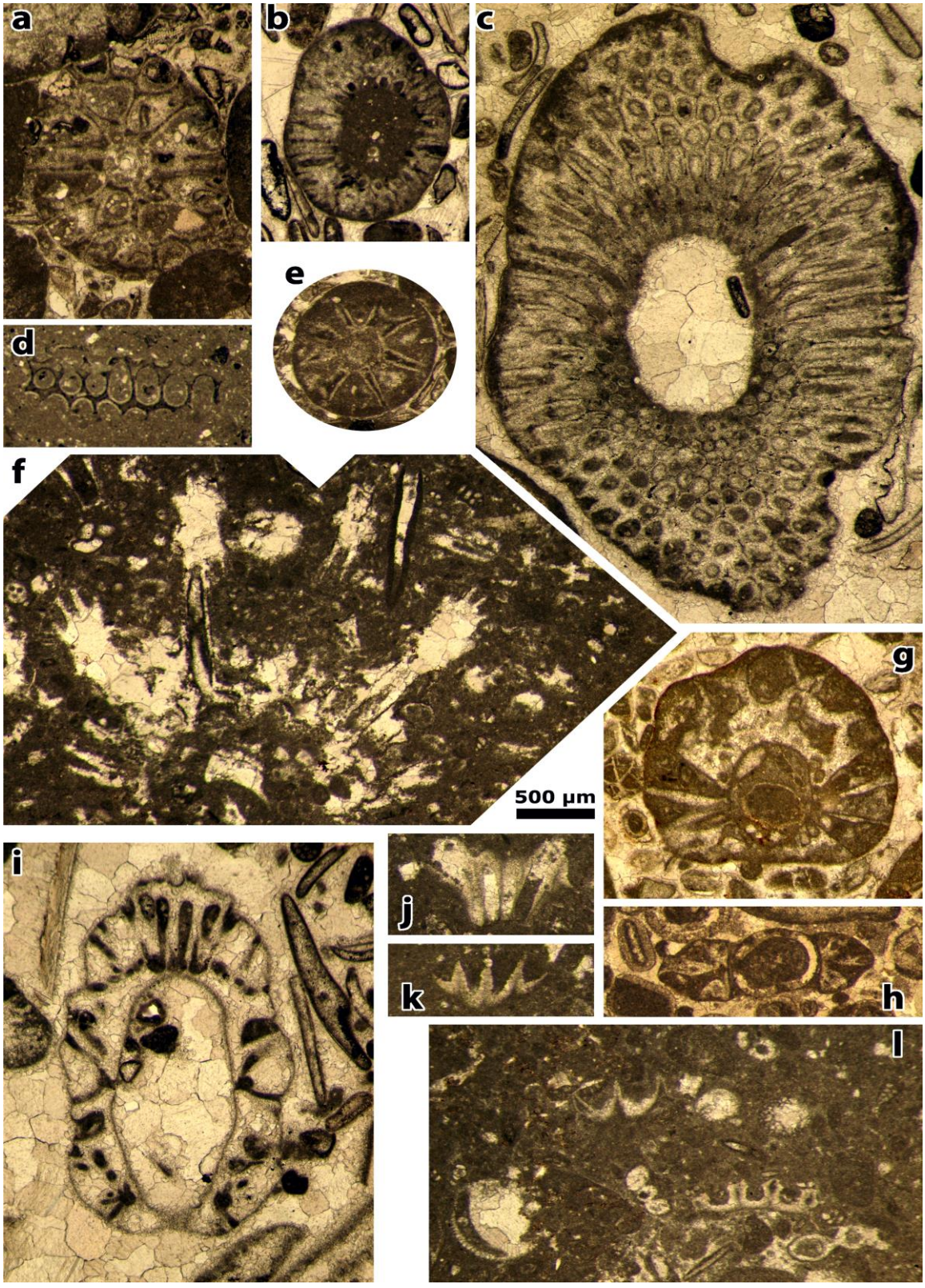

Fig. 3 a to l (scale bar : 500 µm): **a** oblique section of *Zergabriella embergeri*, Chambotte Fm, Upper Berriasian, sample 253 ; **b** oblique section of *Triploporella* ? *praturloni*, "Calcaires roux", Lower Valanginian, sample 241; **c** oblique section of *Triploporella* ? *praturloni*, "Calcaires roux", Lower Valanginian, sample 241.60; **d** tangential section of *Zergabriella embergeri*, Vions Fm, Upper Berriasian, sample 258; **e** transverse section of *Zergabriella embergeri*, Chambotte Fm, Upper Berriasian, sample 253; **f** oblique section of a verticil of *Selliporella neocomiensis*, transition Vions - Pierre Châtel formations, Middle-Upper Berriasian, sample 291.80; **g** oblique section of *Falsolikanella danilovae*, "Urgonien jaune", Upper Hauterivian, sample 116; **h** subaxial section of a verticil of *Falsolikanella danilovae*, "Urgonien jaune", Upper Hauterivian, sample 107; **i** oblique section of *Dissocladella intercedens* "Calcaires roux", Lower Valanginian, sample 241.60; **j** tangential section of a verticil of *Clypeina sulcata*, Pierre Châtel Formation, Middle Berriasian, sample 317; **k** oblique section of a verticil of *Clypeina sulcata*, Pierre Châtel Formation, Middle Berriasian, sample 317; **l** random sections of verticils of *Clypeina sulcata*, Pierre Châtel Formation, Middle Berriasian, sample 318.

octocorallian debris, a view that we do not share. We identify Carpathoporellas in both Urgonian units

Family Polyphysaceae (Kützing)
The characteristic of the representatives of this family is to have either two discrete types of laterals, some sterile and others fertile, alternating along the main axis, or verticils of elongated reproductive organs. However, in modern forms, a single terminal fertile verticil called a cap is common; this last feature is called the umbrellosporate type.

Genus *Actinoporella* (Gümbel)
Actinoporella gr. *podolica* (Alth)
(Fig. 4l-n; Fig. 5i)
We use "gr." to indicate that in our opinion we are not dealing with a single species but possibly with several (Granier, 1995). These forms were identified in both Upper Hauterivian Urgonian units as well as in the Middle Berriasian Pierre Châtel Formation.

Genus *Angioporella* Masse *et al.*
Angioporella fouryae Masse *et al.*
(Fig. 6o; Fig. 7l, n)
We identified it only in the "Urgonien jaune".

Genus *Clypeina* (Michelin)
The fossil genus *Clypeina* comprises some forty species, of which we identified two in the cores studied. It is worth mentioning that, although *Clypeina paucicalcarea* (Conrad), which was recently revised (Granier, 2013a), is a classical species of older Urgonian deposits (Clavel *et al.*, 2007, 2013), we did not observed it in the material studied.
Clypeina parasolkani (Farinacci & Radoičić)
(Fig. 5j-m; Fig. 6h-l)
This species is common within the Pierre Châtel Formation, up to its transition into the Vions Formation (*Clypeina* aff. *parasolkani*: Fig. 5n-o).

Clypeina sulcata (Alth)
(Fig. 3j-l)
This well known species, which may appear in the literature as *Cl. jurassica* Favre *in* Favre & Richard, is the second species of dasycladalean algae listed here that is mineralized with calcite instead of aragonite (Conrad & Varol, 1990; Granier, 2012). It is found only in the lowermost Pierre Châtel Formation.

Genus *Otternstella* Granier *et al*.
Otternstella lemmensis (Bernier)
(Fig. 5p)
This species, excluded from the genus *Heteroporella* (Praturlon) by Granier *et al.* (1995), was found only in the lowermost part of the Pierre Châtel Formation.

Genus *Pseudoactinoporella* (Conrad)
Though Granier (1995) suggested a possible synonymy with the genus *Actinoporella* (Gümbel), the occurrence of a basal expansion on some laterals does not appear to be a permanent feature that would support this opinion.
Pseudoactinoporella fragilis (Conrad)
(Fig. 6e-f)
This species is a classical species of Urgonian deposits and spans the Late Hauterivian to the Bedoulian times; to date it was never found in Lower Hauterivian strata. We identify it both in the "Urgonien jaune" and in the "Urgonien blanc".

Genus *Pseudoclypeina* Radoičić
(Fig. 7o)
Within a verticil, as for the genus *Clypeina* (Michelin), the primary laterals merge in their proximal part. Some species have a second order of laterals, others have three orders. Specimens referable to this genus have two orders of laterals and are found only in the "Urgonien blanc".

Genus *Conradella* Masse & Bucur
Conradella bakalovae (Conrad & Peybernès)
(Fig. 6g)
According to Masse and Bucur (2002) the range of *Conradella bakalovae* (Conrad & Peybernès) spans "the Hauterivian (?) - Early Aptian interval". Its record in sample 134 near the base of "Urgonien jaune" validates at least a Late Hauterivian age for its older occurrence.

Family Thyrsoporellaceae Granier & Bucur *in* Granier *et al.*
The characteristic of the advanced representatives of this family is to have their reproductive organs sited in both primary and higher orders of the laterals. This feature was termed the syringosporate type by Granier and Bucur (Granier *et al.*, 2013a, 2013b).

Genus *Deloffrella* Granier & Michaud
Deloffrella hauteriviana (Masse *in* Masse *et al.*)
(Fig. 5c; Fig. 7p, r)
This tiny species was recently revised (Granier, 2013b). It was transfered from the genus *Dissocladella* (Pia *in* Rao & Pia), which is part of the Family Triploporellaceae, to the genus *Deloffrella* Granier & Michaud, which is part of the Family Thyrsoporellaceae. The Dissocladellas have two orders of laterals and they are cladosporate (see below); on the other hand, the Deloffrellas have four orders of laterals and they are syringosporate. According to Clavel *et al.* (2007, 2013), *Deloffrella hauteriviana* is not younger than the earliest Barremian. In the cored section, it was identified twice, within the "Pierre jaune de Neuchâtel" (reworked) and at the eroded top of the "Urgonien blanc".

Deloffrella quercifoliipora Granier & Michaud
(Fig. 6m)
Selected references:
1987 *Deloffrella quercifoliipora* n.gen. n.sp.- Granier & Michaud, Pl. I, figs. 1-10, San Ricardo Formation, Kimmeridgian-Tithonian, Poblado Catorce, Chiapas (Mexico)
1990 *Deloffrella quercifoliipora*.- Conrad & Varol, Fig. 8 (right), ? Hauterivian, Elburz (Iran)
2013b *Deloffrella quercifoliipora* Granier & Michaud.- Granier, Fig. 4.10, Morand borehole, -271m, Vions Formation, Upper Berriasian, Montricher, Vaud (Switzerland)
Initially described from uppermost Jurassic strata in Chiapas, Mexico (Granier & Michaud, 1987), this

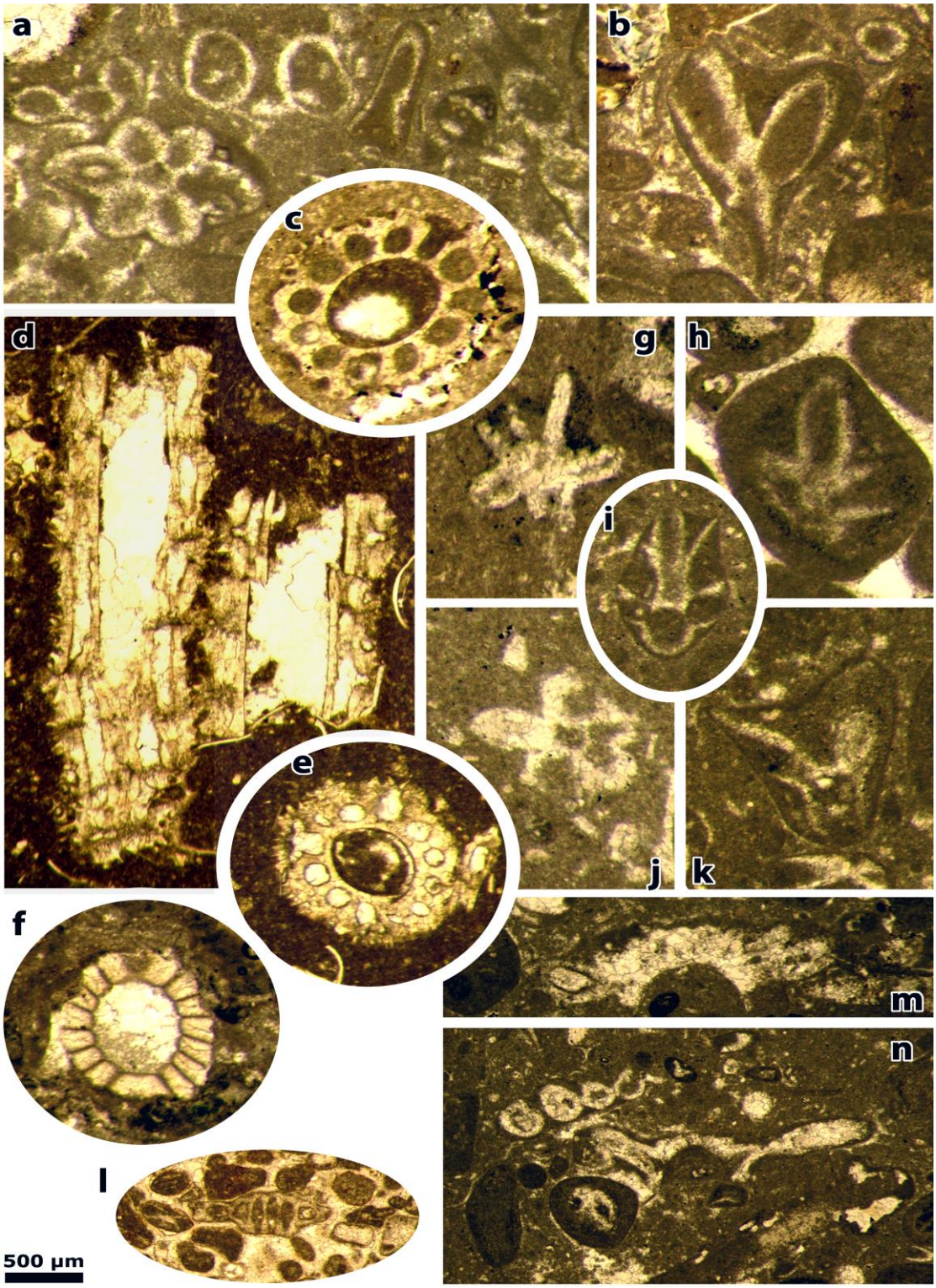

Fig. 4 a to n (scale bar : 500 µm): **a** random sections of laterals of *Rajkaella bartheli*, transition Pierre Châtel - Goldberg formations, Lower-Middle Berriasian, sample 320; **b** section of a lateral of *Rajkaella bartheli*, transition Pierre Châtel - Goldberg formations, Lower-Middle Berriasian, sample 320; **c** transverse section of a charophyte stalk, *Charaxis* sp., Goldberg Fm, Lower Berriasian, sample 324; **d** axial sections of charophyte stalks, *Charaxis* sp. , Goldberg Fm, Lower Berriasian, sample 325; **e** transverse section of a charophyte stalk, Goldberg Fm, Lower Berriasian, sample 325; **f** axial section of a charophyte oogonium, Goldberg Fm, Lower Berriasian, sample 321; **g** tufts of secondary laterals of *Rajkaella bartheli*, Pierre Châtel Formation, Middle Berriasian, sample 303; **h** tufts of secondary laterals of *Rajkaella bartheli*, Pierre Châtel Formation, Middle Berriasian, sample 316; **i** section of a lateral of *Rajkaella bartheli*, Pierre Châtel Formation, Middle Berriasian, sample 319; **j** tufts of secondary laterals of *Rajkaella bartheli*, Pierre Châtel Formation, Middle Berriasian, sample 303; **k** section of a lateral of *Rajkaella bartheli*, Pierre Châtel Formation, Middle Berriasian, sample 319; **l** deep tangential section of a verticil of *Actinoporella* sp. (note: the corona structure is visible), "Urgonien jaune", Upper Hauterivian, sample 114; **m** oblique section of a verticil of *Actinoporella* sp., Pierre Châtel Formation, Middle Berriasian, sample 319 ; **n** random sections of verticils of *Actinoporella* sp., Pierre Châtel Formation, Middle Berriasian, sample 319.

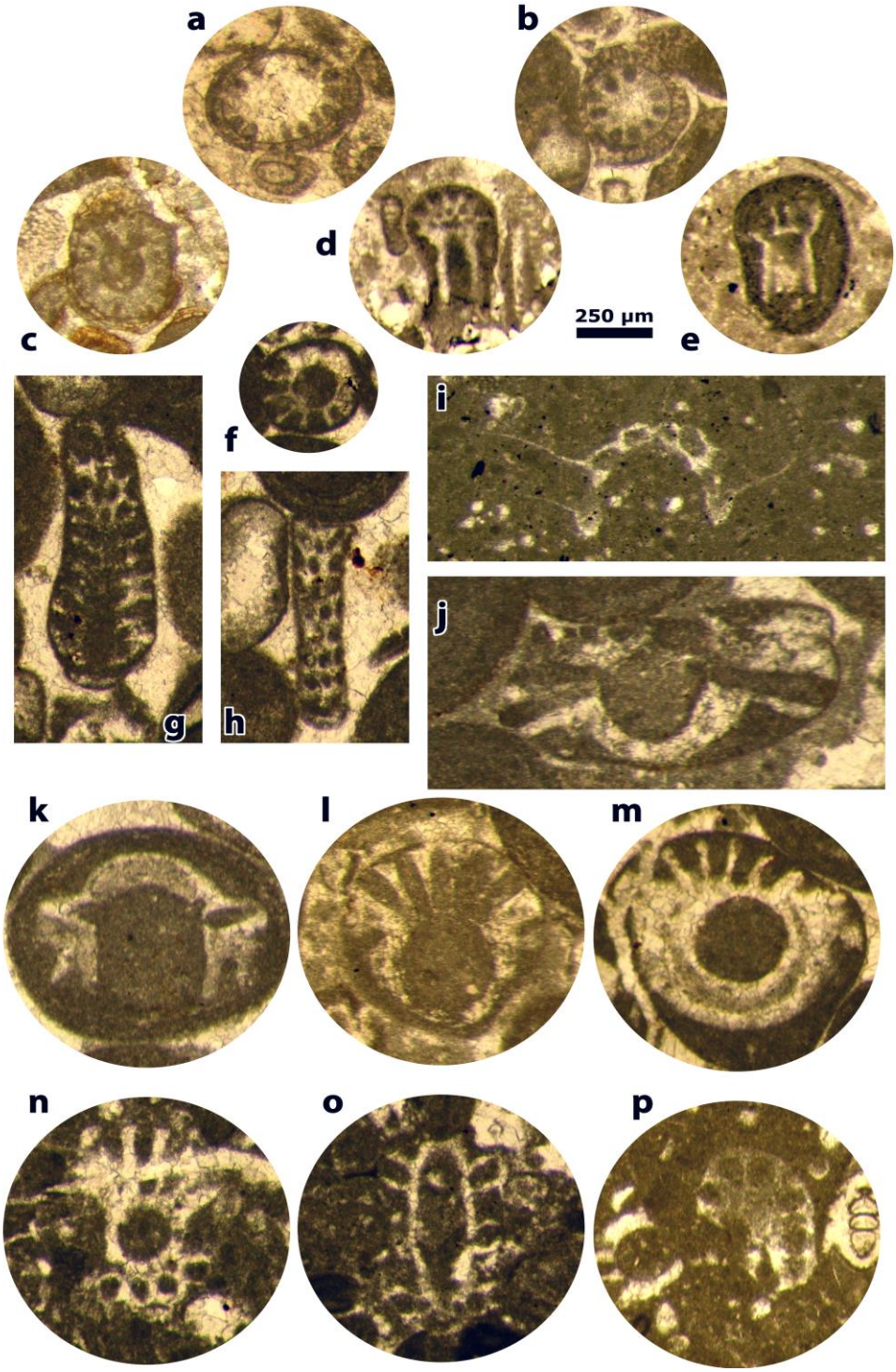

Fig. 5 a to **p** (scale bar : 250 µm): **a** random section of *Terquemella* sp., "Urgonien jaune", Upper Hauterivian, sample 107; **b** random section of *Terquemella* sp., "Urgonien jaune", Upper Hauterivian, sample 128; **c** subtransverse section of *Deloffrella hauteriviana*, " Pierre jaune", Lower Hauterivian, sample 171; **d** section of a lateral of *Rajkaella minima*, Vions Fm, Upper Berriasian, sample 287; **e** section of a lateral of *Rajkaella minima*, Pierre Châtel Formation, Middle Berriasian, sample 312; **f** subtransverse section of *Salpingoporella steinhauseri*, Pierre Châtel Formation, Middle Berriasian, sample 307; **g** oblique section of *Salpingoporella steinhauseri*, Pierre Châtel Formation, Middle Berriasian, sample 307; **h** tangential section of *Salpingoporella steinhauseri*, Pierre Châtel Formation, Middle Berriasian, sample 307; **i** oblique section of a verticil of *Actinoporella* sp. (note: the corona structure is visible), Pierre Châtel Formation, Middle Berriasian, sample 301; **j** oblique section of a verticil of *Clypeina parasolkani*, Pierre Châtel Formation, Middle Berriasian, sample 310; **k** subaxial section of a verticil of *Clypeina parasolkani*, Pierre Châtel Formation, Middle Berriasian, sample 310; **l** oblique section of a verticil of *Clypeina parasolkani*, Pierre Châtel Formation, Middle Berriasian, sample 310; **m** subtransverse section of a verticil of *Clypeina parasolkani*, Pierre Châtel Formation, Middle Berriasian, sample 309 ; **n** oblique section of *Clypeina* aff. *parasolkani* (two fertile verticils visible), transition Vions - Pierre Châtel formations, Middle-Upper Berriasian, sample 291.8; **o** subaxial section of *Clypeina* aff. *parasolkani* (three fertile verticils visible), transition Vions - Pierre Châtel formations, Middle-Upper Berriasian, sample 291.8; **p** oblique section of *Otternstella lemmensis*, Pierre Châtel Formation, Middle Berriasian, sample 317

Tethyan species has been reported several times from discrete localities (Senegal, Algiers, Romania, Iran, *etc.*). Its total stratigraphic range spans the Kimmeridgian to the Aptian times (Granier & Deloffre, 1993). Here it is found only in the Vions Formation.

Genus *Zergabriella* Granier
Zergabriella embergeri (Bouroullec & Deloffre)
(Fig. 3a, d-e)
Selected references:
1987 *Macroporella embergeri* Bouroullec & Deloffre.- Bucur & Oros, Pl. VI, fig. 3, Crivina marls, Upper Beriasian-Valanginian, Illidia, Reşiţa Zone (Romania)
1989*Zergabriella embergeri*, n.gen., n.comb.- Granier, synonymy to date, Pl. 1, figs. 1-7; Pl. 2, figs. 1-9, various localities
2010 *Zergabriella embergeri*.- Granier, synonymy to date, Figs. 1-5, Pls. 1-4, various localities.
This is a third species that becomes mineralized with calcite instead of aragonite (Granier, 2012). It is found in both Vions and Chambotte formations.

Family Triploporellaceae (Pia)
Genus *Dissocladella* (Pia *in* Rao & Pia)
Dissocladella intercedens Bakalova
(Fig. 3i)
Selected references:
1975 *Petrascula bursiformis* (Etallon).- Dragastan, Pl. XL, fig. 3, Upper Tithonian, Fagetul Ciucului Mts. (Romania)
1978 *Dissocladella intercedens* sp.n.- Bakalova, Pl. 1, figs. 4 & 6 (detail of 4), Brestnica Formation, Upper Tithonian - Lower Berriasian, borehole Várbica (Varbitsa, Bulgaria)
1993 *Dissocladella* aff. *intercedens* Bakalova.- Bucur, Pl. 1, figs. 5, 7-18, Crivina marls, Upper Berriasian-Lower Valanginian, Illidia, Reşiţa Zone (Romania)
1994 *Dissocladella* aff. *intercedens* Bakalova.- Bucur, Pl. XIV, fig. 9 [= Bucur, 1993, Pl. 1, fig. 7]
The specimen found in sample 241.60 from the Lower Valanginian "Calcaires roux" is the unique section of this species (Fig. 3i).
In addition to this species we ascribe, with some reservation, to this genus one tiny specimen of a tubular verticillated alga with two orders of laterals (Fig. 7q). It was found in the “Urgonien blanc”.

Genus *Rajkaella* Dragastan & Bucur
The dispute regarding this taxon (Granier, 1987b, 1990, 1991; Dragastan & Bucur, 1988, 1993) ended almost as quickly as it started with the adoption of the generic name *Rajkaella* to replace "*Radoiciciella*" (Granier & Deloffre, 1993). The genus differs from *Pseudoclypeina* Radoičić because the primary laterals of a verticil are clearly separated in their proximal part. We identified two representatives of the genus in the cores analysed.
Rajkaella bartheli (Bernier)
(Fig. 4a-b, g-k)
This species has rather large secondary laterals. It is found only in Vions Formation.

Rajkaella minima (Jaffrezo)
(Fig. 5d-e)
Specimens referable to this species have small secondary laterals as the specific epiteth indicates it. They are found in both the Vions and Pierre Châtel formations.

Genus *Salpingoporella* (Pia *in* Trauth)
This genus includes more than thirty species (Bassoullet *et al.*, 1978; Granier & Deloffre, 1993; Carras *et al.*, 2006) with distally-enlarged (phloiophourous) and -open calcified laterals. They are common in the Urgonian lagoonal facies:
- in the "Urgonien blanc", we identified *Salpingoporella genevensis* (Conrad) (Fig. 7d), *S. melitae* Radoičić (Fig. 7i), and *S. muehlbergii* (Lorenz) (Fig. 7a-c). According to Clavel *et al.* (2007, 2013), *S. genevensis* spans the Late Hauterivian and the Early Barremian times;
- in the "Urgonien blanc", we identified *Salpingoporella heraldica* Sokać (Fig. 7k).

In the Pierre Châtel Formation, we found *Salpingoporella annulata* Carozzi (Fig. 6a-c) and *S. steinhauseri* Conrad *et al.* (Fig. 5f-h).
Genus *Suppiluliumaella* Elliott
(Fig. 7e-g, m)
Some large specimens with two orders of laterals are referred to this genus. They are found at the top of the “Urgonien jaune”.

Genus *Triploporella* (Steinmann)
Triploporella ? *praturloni* (Dragastan), nov. comb.
(Fig. 3b-c)
Originally ascribed to the genus *Macroporella* (Pia), a Seletonnellacean alga, this species has features such as euspondyly, *i.e.*, having laterals arranged in verticils, and cladospory, *i.e.*, with cysts in its primary laterals (Bucur, 1985), that exclude it. Alternatively it could have been reascribed to the genus *Salpingoporella* (Pia *in* Trauth), a Triploporellacean alga. However due to its huge number of primaries per verticils and their general shape, thin and elongated, I prefer to refer it to the genus *Triploporella* (Steinmann). The question mark following the generic name stands for a species left in open nomenclature as the occurrence of short secondaries is not documented yet. It is a fourth and last species studied that is mineralized with calcite instead of aragonite (Granier, 2012).
Our specimens were found in the "Calcaires roux".

Daycladales of uncertain affinity
Genus *Cylindroporella* Johnson
(Fig. 7j)
The genus *Cylindroporella* Johnson comprises a number of species of uncertain affinities. Following revisions, some species were transferred to the genera *Montiella* L. & J. Morellet and *Fourcadella* Granier & Berthou, *etc*. Here only the few algal remains presenting a neck-like structure (as illustrated by Granier, 1987b, Pl. 34, figs. f-g as "*Cylindroporella barnesii* Johnson") are referred to this genus. They are found at the top of the “Urgonien blanc”.

Genus *Oroseina* Dieni *et al.*
(Fig. 7s-u)

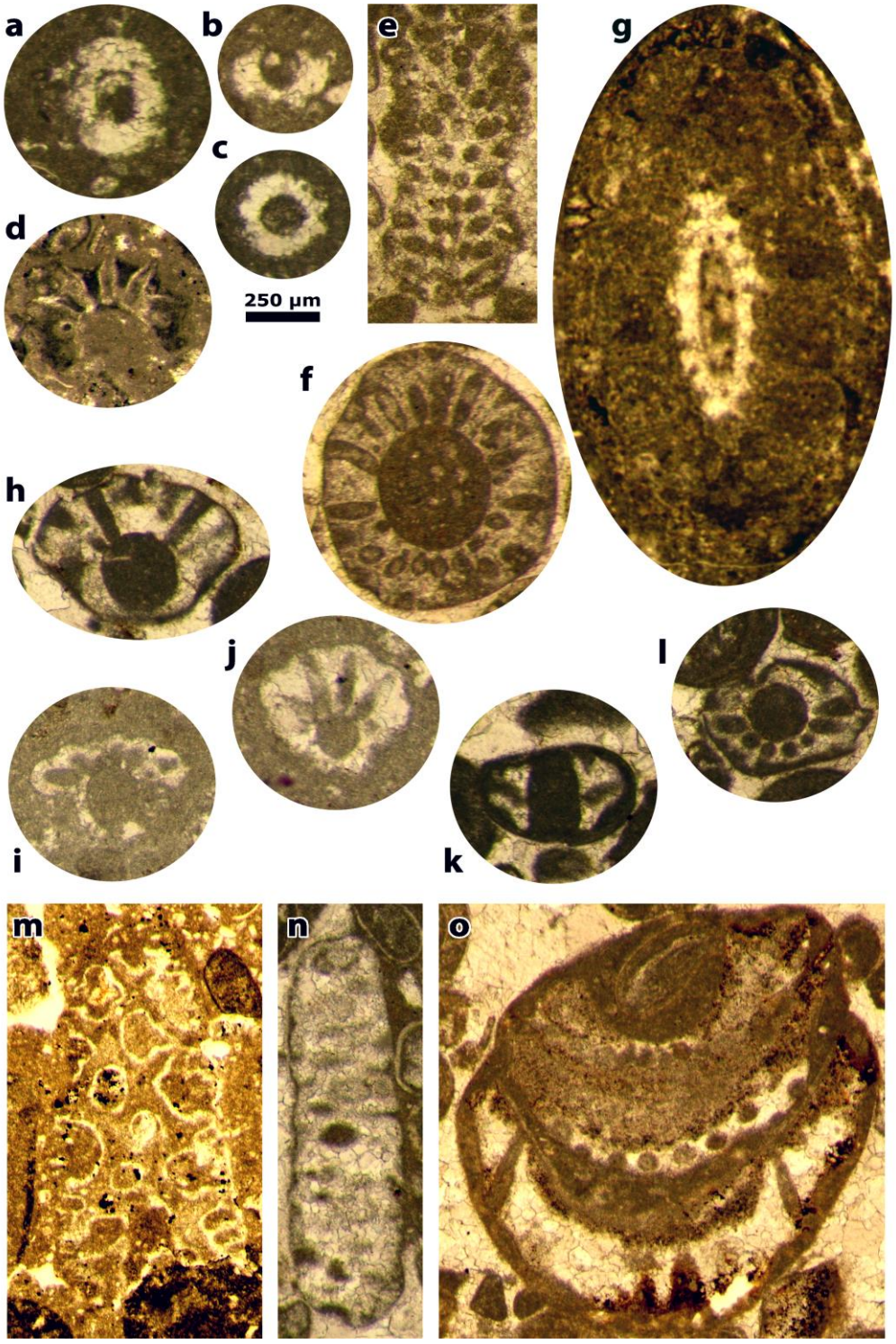

Fig. 6 a to o (scale bar : 250 µm): **a** oblique section of *Salpingoporella annulata*, Pierre Châtel Formation, Middle Berriasian, sample 317; **b** oblique section of *Salpingoporella annulata*, Pierre Châtel Formation, Middle Berriasian, sample 317; **c** subtransverse section of *Salpingoporella annulata*, Pierre Châtel Formation, Middle Berriasian, sample 317; **d** oblique section of *Falsolikanella campanensis*, Vions Fm, Upper Berriasian, sample 270; **e** deep tangential section of *Pseudoactinoporella fragilis*, "Urgonien jaune", Upper Hauterivian, sample 101; **f** oblique section of *Pseudoactinoporella fragilis*, "Urgonien jaune", Upper Hauterivian, sample 107; **g** oblique section of *Conradella bakalovae*, "Urgonien jaune", Upper Hauterivian, sample 134; **h** oblique section of a verticil of *Clypeina parasolkani*, Pierre Châtel Formation, Middle Berriasian, sample 309; **i** oblique section of a verticil of *Clypeina parasolkani*, Pierre Châtel Formation, Middle Berriasian, sample 293; **j** oblique section of a verticil of *Clypeina parasolkani*, Pierre Châtel Formation, Middle Berriasian, sample 293; **k** subaxial section of a verticil of *Clypeina parasolkani*, Pierre Châtel Formation, Middle Berriasian, sample 309; **l** subtransverse section of a verticil of *Clypeina parasolkani*, Pierre Châtel Formation, Middle Berriasian, sample 309; **m** deep tangential section of *Deloffrella quercifoliipora*, Vions Fm, Upper Berriasian, sample 271; **n** random section of *Cymopolia* sp. or *Neomeris* sp., "Urgonien jaune", Upper Hauterivian, sample 115; **o** oblique section of *Angioporella fouryae*, "Urgonien jaune", Upper Hauterivian, sample 129

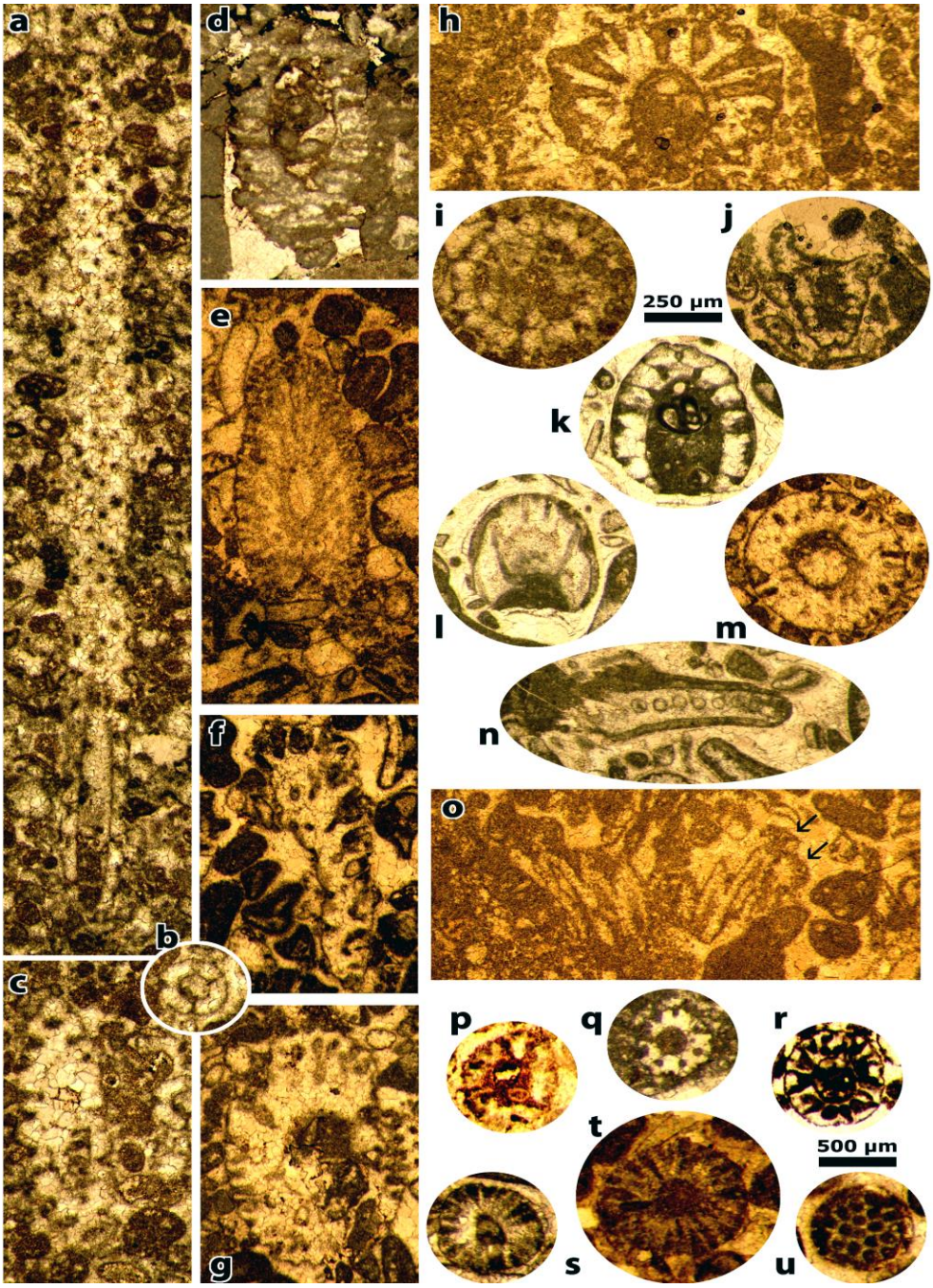

Fig. 7 a to o (scale bar : 250 µm): **a** tangential to oblique section of *Salpingoporella muehlbergii*, "Urgonien blanc", Upper Hauterivian, sample 42; **b** transverse section of *Salpingoporella muehlbergii*, "Urgonien blanc", Upper Hauterivian, sample 42; **c** oblique section of *Salpingoporella muehlbergii*, "Urgonien blanc", Upper Hauterivian, sample 42; **d** oblique section of *Salpingoporella genevensis*, "Urgonien blanc", Upper Hauterivian, sample 40; **e** oblique section of *Suppiluliumaella* sp., "Urgonien jaune", Upper Hauterivian, sample 96; **f** oblique section of *Suppiluliumaella* sp., "Urgonien jaune", Upper Hauterivian, sample 96; **g** oblique section of *Suppiluliumaella* sp., "Urgonien jaune", Upper Hauterivian, sample 96; **h** oblique section of a verticil of *Falsolikanella danilovae*, "Urgonien jaune", Upper Hauterivian, sample 116 ; **i** transverse section of *Salpingoporella melitae*, "Urgonien blanc", Upper Hauterivian, sample 42; **j** oblique section of *Cylindroporella* sp., "Urgonien blanc", Upper Hauterivian, sample 71; **k** oblique section of *Salpingoporella heraldica*, "Urgonien jaune", Upper Hauterivian, sample 115; **l** oblique section of *Angioporella fouryae*, "Urgonien jaune", Upper Hauterivian, sample 115; **m** subtransverse section of *Suppiluliumaella* sp. , "Urgonien jaune", Upper Hauterivian, sample 96; **n** tangential section of a sterile verticil of *Angioporella fouryae*, "Urgonien jaune", Upper Hauterivian, sample 115; **o** tangential section of a verticil of *Pseudoclypeina* sp., "Urgonien blanc", Upper Hauterivian, sample 72; **p** to u (scale bar : 500 µm): p oblique section of *Deloffrella hauteriviana*, "Urgonien blanc", Upper Hauterivian, sample 37.85; q subtransverse section of *Dissocladella* ? sp., "Urgonien blanc", Upper Hauterivian, sample 90; **r** oblique section of *Deloffrella hauteriviana*, "Urgonien blanc", Upper Hauterivian, sample 37.85; **s** axial section of *Oroseina* sp., "Urgonien jaune", Upper Hauterivian, sample 114; **t** random section of *Oroseina* sp., "Urgonien jaune", Upper Hauterivian, sample 112; **u** tangential section of *Oroseina* sp., "Urgonien jaune", Upper Hauterivian, sample 112.

In the “Urgonien jaune”, we identified few “rosette”-like structures, which are referred to *Oroseina* Dieni et al.

DISCUSSION

A) Biostratigraphy.

The interval studied that spans Tithonian to Hauterivian strata permits an overview of most families (6 out of 7) of the Order Dasycladales. Many species (*Angioporella fouryae*, *Clypeina parasolkani*, *Cl. sulcata*, *Deloffrella hauteriviana*, *Falsolikanella campanensis*, *F. danilovae*, *Selliporella neocomiensis*, *Otternstella lemmensis*, *Rajkaella bartheli*, *Rajkaella minima*, *Salpingoporella annulata*, *S. genevensis*, *S. steinhauseri*, *Triploporella* ? *praturloni*, *Zergabriella embergeri*), alone or in combination with benthic foraminifers, confirm, or at least do not contradict, the ages ascribed to the lithostratigraphic units on the basis of regional correlations (Charollais *et al.*, 2008). For the Berriasian-Lower Valanginian, the algae can be combined with benthic foraminifers such as *Ammocycloloculina erratica* (Joukowsky & Favre) *Montsalevia salevensis* (Charollais *et al.*), *Pfenderina neocomiensis* (Pfender), *Pseudocyclammina lituus* (Yokohama), *Pseudotextulariella courtoniensis* (Brönnimann), *Valdanchella miliani* (Schroeder) (see examples in Granier, 1987b, Granier & Bucur, 2011, Bucur *et al.*, 2014). To identify the Hauterivian, the algae should be combined with orbitolinids. *Choffatella decipiens* Schlumberger is not an age-diagnostic fossil but, where it is not associated with algae, it is a good proxy for maximum flooding episodes (Granier & Busnardo, 2013).

B) The nature of the carbonate sedimentation: photozoan versus heterozoan production.

With respect to the Early Cretaceous paleo-environments, many intervals (Goldberg, Pierre Châtel, Vions, and Chambotte formations, "Calcaires roux", "Urgonien jaune", and "Urgonien blanc") correspond to shallow-water sedimentation, either low-energy (in a protected lagoon) or high-energy (in reefal environments *sensu lato* and oolitic shoals), *i.e.*, the "factory" for "photozoan carbonates" (see Lees & Bulter, 1972). On the other hand the skeletal components of the remaining intervals ("Marnes d'Arzier", "Marnes d'Hauterive", "Mergelkalk Zone", and "Pierre Jaune"), which consist mainly of echinoderm, serpulid and bryozoan remains, point to the production of "heterozoan carbonates" (see Lees & Bulter, 1972).

Here there are only two options:

- the first option is to assume (against all odds) that heterozoan and photozoan carbonates represent two discrete types of carbonate deposition that do exclude each other;
- the second option is to consider that both types can coexist in laterally adjacent environments, *i.e.*, merely an illustration of Walther's "Law of Facies". Actually, photozoan carbonates, which represent the biogenic production in shallow warm sea waters, are always accompanied by heterozoan carbonates in the deeper and cooler adjacent environments.

A few authors (Föllmi, 2012; Godet *et al.*, 2013) deny the existence of any photozoan carbonates in the Valanginian, Hauterivian and Lower Barremian strata of W Switzerland and SE France (see discussions in Conrad *et al.*, 2012; Charollais *et al.*, 2013; Granier *et al.*, 2013, 2014) because such existence conflicts with their model.

To support their views, Godet *et al.* (2013) do not hesitate to manipulate data; see for instance the column "Provence" in their Fig. 2, *op. cit.*, supposedly derived from facts documented by Leonide *et al.* (2012). They focus on the “studied area” window that fits with their theory and deliberately avoid the larger window (Leonide *et al.*, 2012, Fig. 2) that proves they are wrong.

At Éclépens and in the Morand drilling, the Urgonian facies, both the "Urgonien jaune" and the "Urgonien blanc", are biostratigraphically dated Late Hauterivian (Conrad *et al.*, 2012; Charollais *et al.*, 2013, and references therein). However, on the basis of the interpretation of their geochemical data, Godet *et al.* (2013) state that these units should be ascribed a Late Barremian age. Charollais *et al.* (2013) have demonstrated that the same geochemical data can also support the alternative Late Hauterivian age.

At Éclépens and in the Morand drilling, the "Pierre jaune" is referred to the Lower Hauterivian (Conrad *et al.*, 2012; Charollais *et al.*, 2013). According to Godet *et al.* (2013), the upper part of this formation is Late Hauterivian and the lower part Early Hauterivian. The development of oolitic facies in the upper "Pierre jaune", which is Hauterivian in age in both interpretations, goes against the model of Föllmi (2012) and followers (Godet *et al.*, 2013) who deny the existence of any photozoan carbonates in Hauterivian times.

Similarly, in the Morand drill core, the diversity of the Dasycladales in the "Calcaires roux" bears witness to the existence of photozoan carbonates in Early Valanginian times contradicting again Föllmi's views (2012).

CONCLUSION

The interval studied that spans Tithonian to Hauterivian strata permits an overview of most families (6 out of 7) of the Order Dasycladales. A number of species, alone or in combination with benthic foraminifers, confirm, or at least do not contradict, the ages ascribed to the lithostratigraphic units on the basis of regional correlations (Charollais *et al.*, 2008).

We recall that heterozoan carbonate production does not exclude occurrence of photozoan carbonate production in laterally shallower areas. This is demonstrated herein again (if necessary) at least for parts of the Valanginian and the Hauterivian stages. As a matter of facts, the find of dasycladalean algae in most of the studied section (Berriasian, Lower and Upper Hauterivian, locally in the Lower Valanginian units) testifies the existence of photozoan carbonate production during the corresponding time intervals, contrary to Föllmi‘s opinion (2012), *i.e.*, the indefensible theory of a huge heterozoan-only interval spanning the whole Valanginian, Hauterivian and Early Barremian times.

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