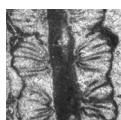


# Late Viséan–early Serpukhovian cyanobacteria and algae from the Montagne Noire (France); taxonomy and biostratigraphy

DANIEL VACHARD, PEDRO CÓZAR, MARKUS ARETZ & ALAIN IZART



A revision of the late Mississippian (late Viséan–early Serpukhovian) cyanobacterial and algal assemblages of Montagne Noire (Aude-Hérault, France) is undertaken, mainly based on new data recently obtained with the foraminiferal assemblages of this area. In this taxonomic contribution, one tribe Borlatellae trib. nov. is translated, and three new genera *Ortonellopsis* gen. nov., *Anchisolenopora* gen. nov. and *Neoradiosphaeroporella* gen. nov., and four new species of algae are described: *Ortonellopsis laxa* gen. et sp. nov., *Anatolipora macroporelloidea* sp. nov., *Paraepimastopora somervillei* sp. nov., and *Neoradiosphaeroporella aprica* gen. et sp. nov. In the Algospongia (incertae sedis algae), the genera *Zidella*, *Valuzieria* emend. herein and *Asteroaoujgalia* are revised. Most of the species appear to be restricted to the latest Viséan–early Serpukhovian interval in the Montagne Noire, and thus, they have to be investigated in coeval Tethyan and Uralian areas for their possible biostratigraphic importance. • Key words: algae, Viséan, Serpukhovian, Montagne Noire, southern France, systematics, biostratigraphy.

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On the southern slope of the Montagne Noire (southern France), the lithologic unit called “calcaires à *Productus*” is composed of small to large carbonate lenses embedded within a very thick lower Carboniferous siliciclastic complex (Fig. 1A) which are generally interpreted as olistoliths and flysch, respectively. Several authors demonstrated that these successions are late Viséan to early Serpukhovian in age (Böhm 1935; Gèze 1949; Mamet 1968; Vachard 1974a, b, 1977a, b; Engel *et al.* 1982; Feist & Galtier 1985; Poty *et al.* 2002; Aretz 2002, 2016; Vachard & Aretz 2004; Korn & Feist 2007; Pille 2008; Vachard *et al.* in press). The eight foraminiferal regional biozones of Vachard *et al.* (in press) significantly refine the stratigraphic frame for the Viséan–Serpukhovian boundary interval in the Montagne Noire. Because of problems with the classical biozonations and substages in northern England, as well as in northern France and Belgium, Vachard *et al.* (in press) mainly compared the biozones of the Montagne Noire with the Russian standard substages (Fig. 1B). Hence, biozones A and B are correlated with the Mikhailovian (that would be correlated with the latest Asbian and earliest Brigantian in western

Europe); the biozones C, D and E are correlated with the Venevian (equivalent to the upper part of the early Brigantian in western Europe), and the biozones F, G and H are correlated with the Tarusian (lower part of the late Brigantian in northern England). Foraminiferal markers of the Steshevian (late early Serpukhovian) might be present in the foraminiferal assemblages of the biozones G and H. The aims of this paper are: 1) to describe new cyanobacterial and algal taxa from the Montagne Noire; 2) to include the distribution of the cyanobacteria, algae and algospongia in the new biostratigraphic scheme of Vachard *et al.* (in press); and 3) to characterize some additional stratigraphic biomarkers, distinct of the foraminifers, of the Viséan–Serpukhovian boundary interval.

## Cyanobacterial and algal assemblages

In total, more than 5000 thin sections have been studied from numerous stratigraphic sections. These thin sections belong to three collections of the authors, D. Vachard’s

(labelled as DV-), M. Aretz' (labelled as MA-), and P. Cózar's (labelled as Pc-) collections.

The late Viséan–early Serpukhovian cyanobacteria assemblages are essentially composed of: 1) chabakoviaceans with uniseriate and ramified series of hemispherical to reniform trichomes, entirely or partially mineralized in dark or grayish microgranular calcite (*Renalcis* Vologdin, 1932; Fig. 2A); 2) aphralysiaceans with short, arched trichomes and dark-microgranular or white and microsparitic walls (*Aphralysia* Garwood, 1914, *Sparaphralysia* Vachard in Vachard & Beckary, 1991; Fig. 2B–E); 3) girvanellaceans with cylindrical trichomes with rare or absent pseudo-ramifications, and a dark-microgranular wall (*Girvanella* Nicholson & Etheridge, 1878, *Mitcheldeania* (Wethered, 1886) Mamet & Roux, 1975b; Fig. 2F); 4) garwoodiaceans with frequent ramifications (*Ortonella* Garwood, 1914, *Ortonellopsis* gen. nov., *Garwoodia* Wood, 1941; Figs 2G, 3A–G); in addition to this skeletal cyanobacteria, various biocalcifications generally assigned to this phylum were found, in the form of microbialites (*sensu* Brune & Moore 1987 and Riding 1991; = spongiostromids, clotted textures, loferites, or thrombolites *auctorum*), *?Bacinella* Radoicic, 1959, *Nostocites* Maslov, 1929 and *Baccanella* Pantic, 1971 (= *Palaeomicrocodium* Mamet & Roux, 1983).

Red algae mainly comprise: 1) elianellaceans (*Anchisolenopora* gen. nov.; Figs 2H, 4A), 2) archaeolithophyllaceans (*Neoprincipia* Cózar & Vachard, 2003 and *Archaeolithophyllum* Johnson, 1956) (Fig. 4B–I); and 3) incerti ordinis (*Hortonella* Mamet, 1995 *ex* Cózar & Vachard, 2005; Fig. 4E).

Green algae mainly comprise: 1) questionable bryopsidales and 2) dasycladales. The former are composed of: a) udoteaceans? (*Melliporella*? aff. “*magnum*” (*sensu* Lemosquet & Poncet 1977 *non* Endo 1951); Fig. 5A–D), and b) incerti ordinis (*Orthriosiphon* Johnson & Konishi, 1956 and *Saccamminopsis* Sollas, 1921; Fig. 7B, C).

The dasycladales are represented by some epimastoporaceans (*Paraepimastopora* Roux, 1979 emend. Krainer & Vachard, 2002, *Palaepimastoporella* Cózar & Vachard, 2004; Fig. 7D–I), and variegated diploporaceans (see Pille 2008 and Pille & Vachard 2011). They are represented by traditional taxa like *Kulikia* Golubtsov, 1961, *Wind-soporella* Mamet & Rudloff, 1972 *ex* Vachard, 1980, *Eovelebitella* Vachard, 1974a, *Cabrieropora* Mamet & Roux, 1975a, *Guadiatella* Cózar *et al.*, 2007, *Coelosporella* Wood, 1940 and *Nanopora* Wood, 1964 (Fig. 8A–K), and by recently described members of the tribe Borladellinae: *Cabrieroporellopsis* Pille & Vachard, 2011, *Murvielipora* Pille & Vachard, 2011, and *Borladella* Cózar *et al.*, 2007 (Fig. 8L–O). Questionable polyphysaceans are represented by *Neoradiosphaeroporella* gen. nov. (Fig. 9A–G); and questionable dasycladales, by *Koninckopora* Lee, 1912 the latter being rare in the Montagne Noire.

Ulotrichales (or questionable dasycladales) are relatively common *Anatolipora* Konishi, 1956 emend. herein: *A. carbonica* Konishi, 1956 emend. herein and *A. macro-porelloidea* sp. nov. (Fig. 6A–I), and scarce *Richella* Mamet & Roux in Mamet *et al.*, 1987 (Fig. 7A).

The algae *incertae sedis* of the fossil class Algospongia are represented by (1) diversified moravammiales: issinellaceans (*Issinella* Reitlinger, 1954; *Zidella* Saltovskaya, 1984; Fig. 10A, B), anthracoporellopsidaceans (*Crassikamaena* Brenckle, 1985 = *?Evlania* Bykova, 1952, see Falahatgar *et al.* 2015; Fig. 10C); kamaenaceans (*Kamaena* Antropov, 1967, *Kamaenella* Mamet & Roux, 1974; Figs 10O, 11F, G?, H?); palaeoberesellaceans (*Exvotarissella* Elliott, 1970, *Palaeoberesella* Mamet & Roux, 1974; Fig. 10D, R); claracrustaceans (*Asphaltinella* Mamet & Roux, 1978, *Claracrusta* Vachard, 1980, *Praedonezella* Kulik, 1973 *ex* Vachard & Cózar, 2010; Figs 10G, H, 12C); (2) aoujgaliales: aoujgaliceans (*Sinustacheoides* Termier *et al.*, 1977, *Stacheoides* Cummings, 1955b, *Costacheoides* Vachard & Cózar, 2010, *Aoujgalia* Termier & Termier, 1950, *Asteroaoujgalia* Brenckle, 2004, *Epistacheoides* Petryk & Mamet, 1972, and *Roquesselsia* Termier *et al.*, 1977; Figs 10E, F, I–N, P, Q, S), ungdarellaceans (*Ungdarella* Maslov, 1950; Fig. 12A), stacheiaceans (*Stacheia* Brady, 1876, *Fourstonella* Cummings, 1955a *ex* Vachard & Cózar, 2010; Fig. 11A–D), and (3) calcifoliales (*Fasciella* Ivanova, 1973, *Fascifolium* Vachard, Karim & Cózar in Vachard & Cózar, 2010, *Frustulata* Saltovskaya, 1984, *Falsocalcifolium* Vachard & Cózar, 2005 and very rare *Calcifolium* Shvetsov & Birina, 1935; Figs 11E, 12B–J).

## Systematic palaeontology

Phylum Cyanobacteria (Stanier, 1974) *ex* Cavalier-Smith, 2002

Class Cyanophyceae Schaffner, 1909

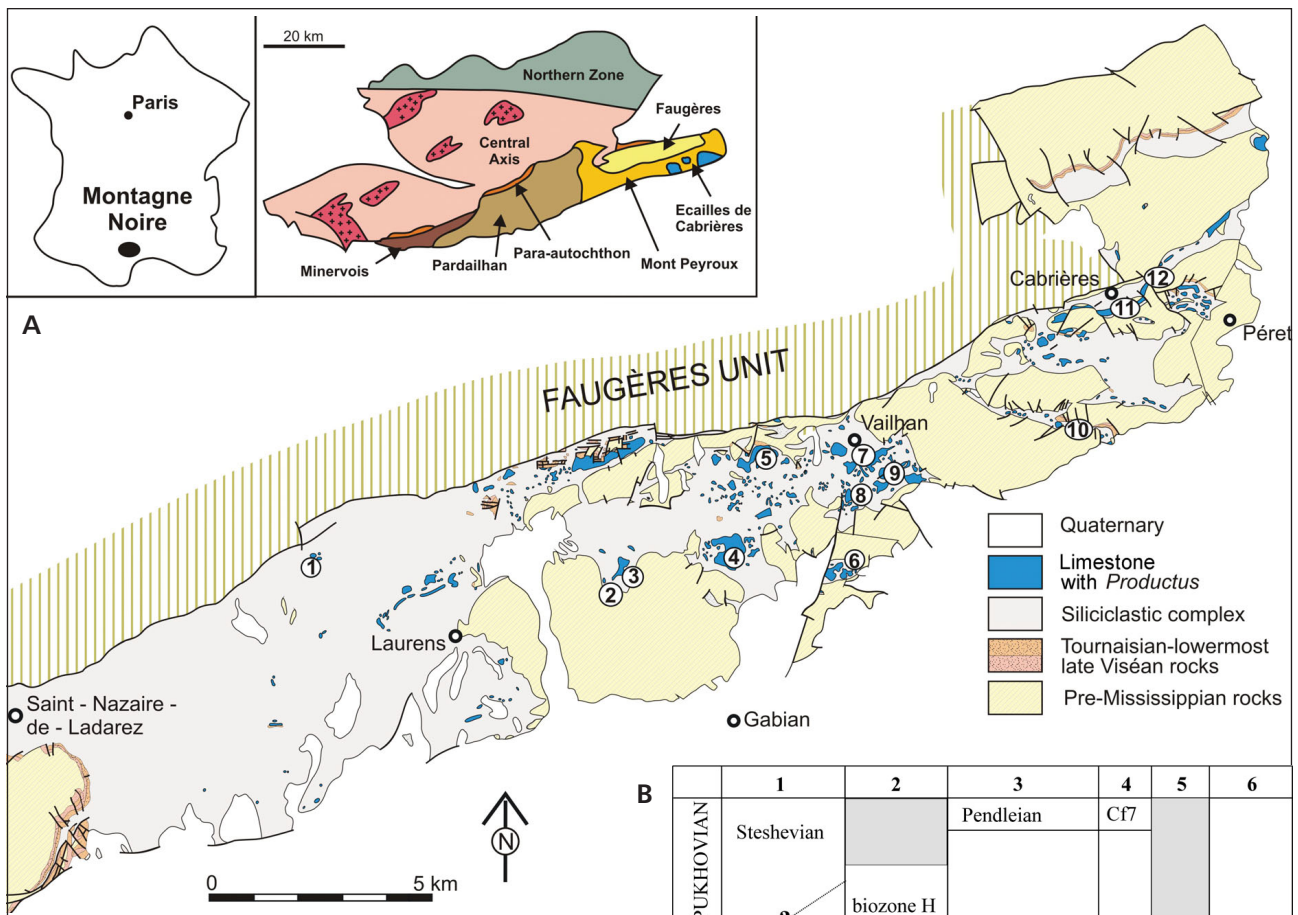
Incerti ordinis

Family Garwoodiaceae Shuysky, 1973

**Description.** – Nodular to elongate colonies of cylindrical trichomes with frequent ramifications with various angle and types of bifurcation. Sheath calcitic, dark-microgranular.

**Remark.** – Prior to the hierarchical translation of Shuysky (1973), sometimes attributed to Johnson (1964) (see Emberger 1976), the group was first named as a tribe by Endo (1961a, p. 24).

**Occurrence.** – Cambrian–Permian, cosmopolitan (*e.g.*, Mamet 1991). Modern equivalents seem to be known



**Figure 1.** A – location of the studied sections and outcrops in the Montagne Noire. 1. La Boutinelle, 2. Castelsec, 3. Roc du Cayla, 4. Les Pascales, 5. Roc de Murviel, 6. Roquemailère, 7. Château-Vailhan, 8. Les Mentaresses, 9. Roque Redonde, 10. La Serre, 11. Japhet, 12. La Serre de Péret. Modified from Aretz (2016) and Vachard *et al.* (in press). • B – correlation of the biozones in the Montagne Noire defined by Vachard *et al.* (in press) with other zonal schemes and biozones from Europe. Column 1. Standard Russian substages. 2. Biozones of the Montagne Noire. 3. Correlation of the Western European substages in the shallow water facies of Pennines (northern England) (according to Cózár & Somerville 2014, 2015). 4. Foraminiferal biozones defined by Conil *et al.* (1980). 5. Traditional biozones in Belgium. 6. Foraminiferal biozones of Poty *et al.* (2006).

(e.g., Riding 1975); therefore, this morphogenus persisted over all fossiliferous times.

### Genus *Ortonellopsis* Vachard & Cózár gen. nov.

*Type species.* – *Ortonellopsis laxa* Vachard & Cózár gen. et sp. nov.

*Etymology.* – Comparable with *Ortonella* (because of the bifurcation of filaments) and ending *opsis*, almost.

*Diagnosis.* – Colonies constituted of loosely packed filaments bifurcating with an acute angle.

*Composition.* – *Ortonellopsis laxa* sp. nov.; *Ortonella mansellensis* Poncet, 1986; *Ortonella myrae* Rácz, 1964.

*Comparison.* – *Ortonellopsis* differs from *Ortonella* in the loose filaments, whereas the angles of bifurcation are similar, from *Gaspsiella* Mamet & Roux in Bourque *et al.*, 1981 in the type of bifurcation, from *Paramitchelleania* Mamet, 2002 in the constant diameter of the trichomes. *Bevocastria magna* Senowbari-Daryan & Link, 2004 has some similarities with *Ortonellopsis*, but differs by its pseudo-septation (conspicuous for instance in the fig. 3d, f–h of Senowbari-Daryan & Link 2004, even if this diagnostic criterion is not mentioned by these authors). Because of this pseudo-septation, *Bevocastria magna* belongs



in reality to the Cretaceous genus *Maurinella* Granier *et al.*, 1991. Due to the absence of pseudo-septation and despite the similarities of some groups of trichomes (see Granier 2015, fig. 25), *Ortonellopsis* gen. nov. differs from *Maurinella*.

**Occurrence.** – Silurian-Triassic of Canada (Poncet 1986), southern France (this work), Spain (Rácz 1964), Carnic Alps (Flügel & Flügel-Kahler 1980), and Greece (Schäfer & Senowbari-Daryan 1983).

***Ortonellopsis laxa* Vachard & Cózar gen. et sp. nov.**

Figure 3A–G

- v. 1974b *Ortonella furcata* Garwood. – Vachard, p. 175, pl. 6, fig. 5, pl. 7, fig. 5.
- v. 1977a *Ortonella furcata* Garwood. – Vachard, p. 374, table 1 (no illustration).
- v. 1977a *Ortonella* aff. *furcata* Garwood. – Vachard, p. 374, table 1.
- v. 1977b *Ortonella furcata* Garwood. – Vachard, p. 136, pl. 1, fig. 2.
- v.p. 2008 *Ortonella* spp. – Pille, pl. 5, figs 1, 2 (non pl. 4, figs 1–7 = true *Ortonella*).
- v. 2008 *Ortonellopsis laxa* Pille, p. 24, pl. 5, figs 3–10 (nomen nudum).

**Etymology.** – Latine *laxus*, loose, because the filaments are loosely spaced.

**Locus typicus.** – Roc de Murviel.

**Stratum typicum.** – Tarusian (earliest Serpukhovian).

**Diagnosis.** – Elongate colonies formed of trichomes bifurcated as in *Ortonella*, but not joined together. The walls of the trichomes are dark-microgranular, whereas the spaces between the trichomes are cemented by a microsparitic calcite.

**Holotype.** – MA-RM83 (Fig. 3D); Aretz' collection, Toulouse.

**Description.** – Outer diameter = 0.032 mm; angle of bifurcation = 40°.

**Type material.** – 25 well-preserved colonies (a base of colony was even observed in the thin section DV227C).

**Comparison.** – *Ortonellopsis laxa* is homeomorphous of *Ortonella furcata* and *Maurinella* sp. *sensu* Granier (2015), although it differs in the genus characters: *i.e.*, from *Ortonella* by microsparitization of the open spaces between

the trichomes, and from *Maurinella* by the absence of pseudo-septation.

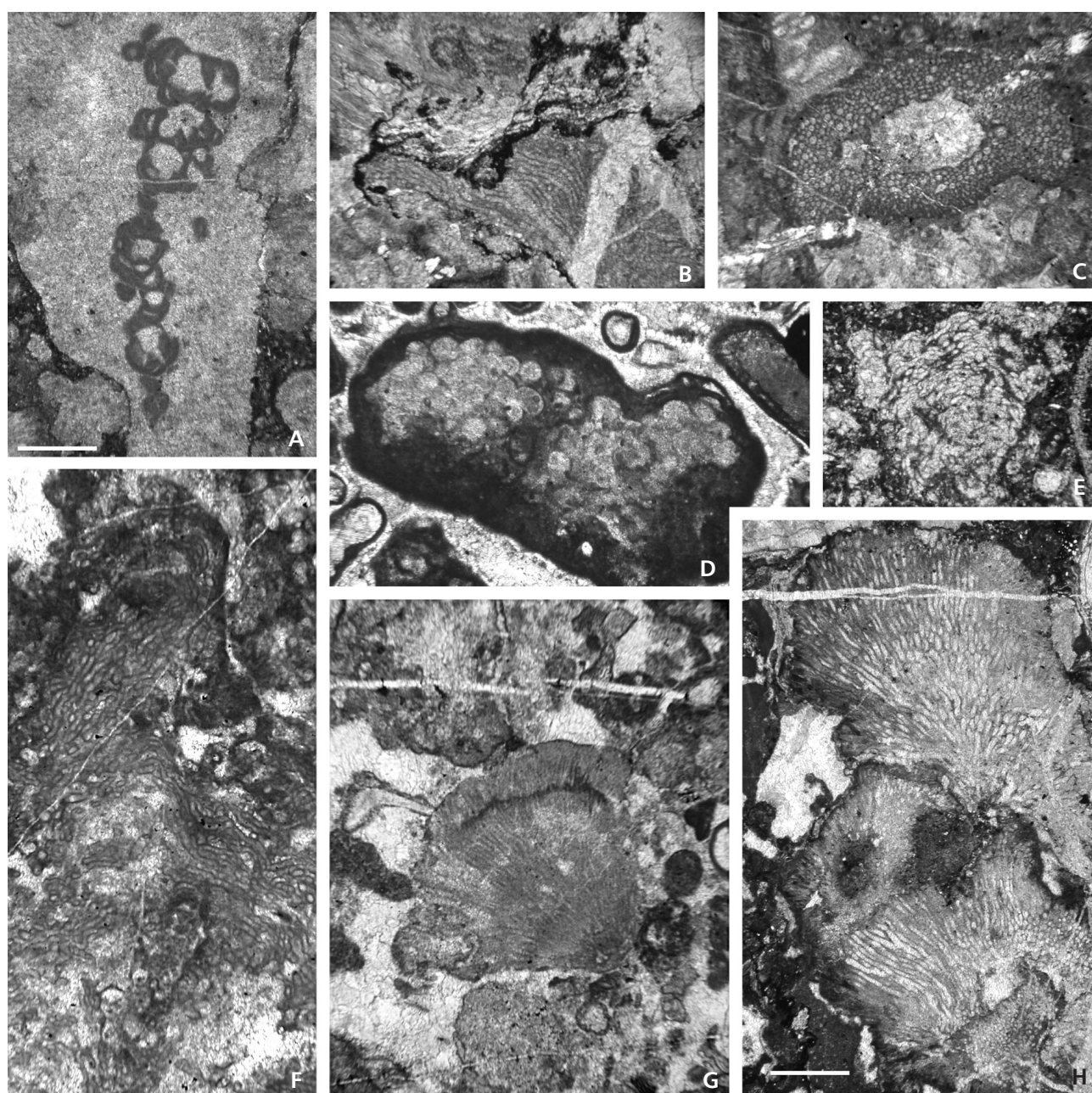
**Remarks.** – It is currently difficult to explain the very rapid microsparitic calcification between the trichomes independently calcified in micrite.

**Occurrence.** – Venevian–Steshevian (latest Viséan–early Serpukhovian = foraminiferal biozones C to G). La Serre-vineyard (DV165A, DV165B, DV165E, DV227B, DV227C, MA-LSV-2004), La Boutinelle (MA-Bou25-13, MA-Bou25-15), Les Pascales (Pc-4618, Pc-4619), Roc du Cayla (Pc-4576, Pc-4597), Château-Vailhan (Pc-4734), Roc de Murviel (MA-330-6, MA-33-6, MA-33-86, MA-33-78, MA-33-76, MA-33-73, MA-33-55, MA-33-54, MA-RM-9, MA-RM-20, MA-RM-21, MA-RM-29, MA-RM-35, MA-RM83, Pc-4503, Pc-4506, Pc-4513, Pc-4462, Pc-4472, Pc-4473, Pc-4908), and Roque Redonde (Pc-4407, Pc-4401, Pc-4399, Pc-4397, MA-RR-81, MA-RR-82, MA-RR-83).

Phylum Rhodophycophyta Papenfuss, 1946

Family Elianellaceae Granier *in* Granier & Dias-Brito, 2016 (= Solenoporaceae Pia, 1927 *auctorum*)

**Remarks.** – The validity and botanical assignment of the family Elianellaceae (formerly “Solenoporaceae”) as a homogeneous taxonomical group have been often questioned (Woelkerling 1988; Brooke & Riding 1998, 2000; Aguirre & Barattolo 2001; Riding 2004; Cózar & Vachard 2006; Granier & Dias-Brito 2016). To partially replace the name Solenoporaceae, Brooke & Riding (1998, 2000) introduced the new family Graticulaceae and compared it to the extant family Sporolithaceae of the order Corallinales (Silva & Johansen 1996). Woelkerling (1988) and Aguirre & Barattolo (2001) considered the “Solenoporaceae” as *incertae sedis* algae. Riding (2004) interpreted the type species *Solenopora spongioides* Dybowski, 1878 as a chaetetid sponge, and assigned the classical Solenoporaceae *Parachaetetes* Deninger, 1906 and *Pseudochaetetes* Haug, 1883 also to chaetetids. In contrast, Riding (2004) considered *Marinella* Pfender, 1939, *Metasolenopora* Yabe, 1912, *Petrophyton* Yabe, 1912 and *Solenoporella* Rothpletz, 1908 as red algae, even though he did not give a new family name for these former algal solenoporaceans. The name Elianellaceae was proposed by Granier *in* Granier & Dias-Brito (2016). We accept this name in order to resolve this old taxonomical problem, even if the first genus name mentioned as synonym for an algal *Solenopora* has been *Metasolenopora* Yabe, 1912 (see *e.g.*, Pia 1927, Peterhans 1929, Poignant 1991), and if the derived family name Metasolenoporaceae would be more reminiscent of Solenoporaceae.



**Figure 2.** Late Viséan–early Serpukhovian cyanobacteria (scale bar = 0.5 mm except for figure H = 2 mm). • A – *Renalcis nubiformis* (Antropov, 1955) Vachard, 1993, thin section MA-RR79, Roque Redonde, early Serpukhovian. • B – *Aphralysia ferreoli* Mamet & Roux, 1975b, thin section MA-CC9B, Castelsec, early Serpukhovian. • C – *Aphralysia carbonaria* Garwood, 1914, thin section MA-RR40, Roque Redonde, latest Viséan. • D – *Sparaphralysia tacia* Vachard in Vachard & Beckary, 1991, thin section DV-293i, Les lentilles de la route, late Viséan. • E – *Aphralysia capriorae* Mamet & Roux, 1975b, thin section MA-LSII-2038, La Serre-vineyard, early Serpukhovian. • F – *Aphralysia ferreoli* Mamet & Roux, 1975b, thin section MA-LSFeldweg 36, La Serre-vineyard, early Serpukhovian. • G – *Ortonella* sp., thin section MA-RM36, Roc de Murviel, latest Viséan. • H – *Anchisolenopora serrana* (Vachard & Aretz, 2004) gen. nov. Holotype, thin section MA-LSI-2043, La Serre-vineyard, early Serpukhovian.

The family Elianellaceae was assigned to *incertae sedis* red algae. We speculate that they are closely related to the Corallinales because several authors have described unquestionable hypothallic and perithallic structures; e.g., in *Pseudochaetetes* (see Peterhans 1929), *Maimonochaete-*

*tes* (see Cózar & Vachard 2006), and in a thallus of *Parachaetetes* from an unpublished material of M. Aretz in the Viséan of Australia. We speculate also that primitive elianellacean taxa, like *Anchisolenopora* gen. nov., *Pseudosolenopora* Mamet & Roux, 1977 and some



*Hedstroemia* Rothpletz, 1913, possibly indicate a relationship between cyanobacteria and corallinales. This hypothesis should be tested with the oldest ellianellacean genus, *Bija* Vologdin, 1932, often associated with numerous Cambrian cyanobacteria.

**Occurrence.** – Cambrian to Palaeocene, perhaps cosmopolitan.

### Genus *Anchisolenopora* gen. nov.

**Type species.** – *Hedstroemia* (?) *serrana* Vachard & Aretz, 2004.

**Synonym.** – *Hedstroemia* (pars); *Solenopora* (pars).

**Etymology.** – Greek *anchi* = almost, and *Solenopora*, related genus.

**Diagnosis.** – Nodular, hemispherical or elongate thallus composed of numerous, densely packed tubes, round to slightly polygonal in cross section, and sharing the same walls. Rare dichotomies occur. In axial section, partitions are absent but some rugosities are visible along the inner surface of the tubes. Wall calcitic, yellowish to brownish.

**Composition.** – *Hedstroemia*? *serrana*; *Hedstroemia nidarosiensis* Høeg, 1932 emend. Roux, 1985; cf. *Hedstroemia sensu* Høeg, 1932 (pl. 8, fig. 7); *Hedstroemia*? sp. *sensu* Johnson & Høeg, 1961 (pl. 11, fig. 5); *Hedstroemia sensu* Riding, 1991, text-fig. 9, p. 68; *Solenopora sensu* Ma *et al.*, 2014 (figs 2.3–3.3?); ?*Hedstroemia*? *koninckopoides* Vachard, 1988; ?*Pseudosolenopora owodenkoi sensu* Mamet, 2002 (pl. 5, figs 10–13) *non* Chanton-Güvenç, 1972a; ?*Pycnoporidium sensu* Flügel, 2004 (pl. 53, fig. 4).

**Comparison.** – The new genus differs from *Hedstroemia* by its tubes systematically in contact each with other, while in *Hedstroemia* only rare tubes are in contact. It differs from the algal “*Solenopora*” in the absence of pseudosepta, from *Pseudosolenopora* by the relatively loose and rounded cross-sections of tubes (no close and polygonal), and the type of wall (no dark-microgranular), from *Guevencipora* Vachard in Vachard *et al.*, 1978 (and from *Solenopora undata* Senowbari-Daryan & Link, 2005 which probably belongs to *Guevencipora*) in the absence of mural pores, and from *Pycnoporidium* Yabe & Toyama, 1928 by the absence of complete transverse partitions.

**Occurrence.** – Ordovician of Norway (Høeg 1932, Roux

1985) and Tarim (NW China; Ma *et al.* 2014). Silurian of Sweden (Riding 1991). Venevian–early Serpukhovian of the Montagne Noire.

### *Anchisolenopora serrana* (Vachard & Aretz, 2004) **comb. nov.**

Figures 2H, 9A

v. 2004 *Hedstroemia* (?) *serrana* Vachard & Aretz, p. 649, fig. 7.3–4.

v. 2008 *Anchisolenopora serrana*; Pille, p. 58, pl. 18, figs 1–7 (nomen nudum).

**Description.** – General dimensions of thallus = 10.000–15.000 × 8.000–10.000 mm. Diameter of tubes = 0.080–0.160 mm.

**Occurrence.** – Latest Viséan (Venevian)–early Serpukhovian of the Montagne Noire (foraminiferal biozones C to H): La Boutinelle (MA-Bou-25.19), Roc du Cayla (MA-12.14), Roque Redonde (Pc4427, MA-RR-27, MA-RR-56, MA-RR-63), Roc de Murviel (MA-28, MA-82, MA-330.4), La Serre-vineyard (MA-LS.I-2043, MA-LS.II-2035, MA-LS.III-2028, MA-LS.IV.B-2015, MA-LS.IV-B, MA-LS.Feldweg. 9, MA-LS.Feldweg. 32, DV227A).

Phylum Chlorophycophyta Papenfuss, 1955  
?Class Bryopsidophyceae Bessey, 1907  
?Order Bryopsidales Schaffner, 1922  
?Family Udoteaceae Feldmann, 1946

### Genus *Mellporella* Rácz, 1964

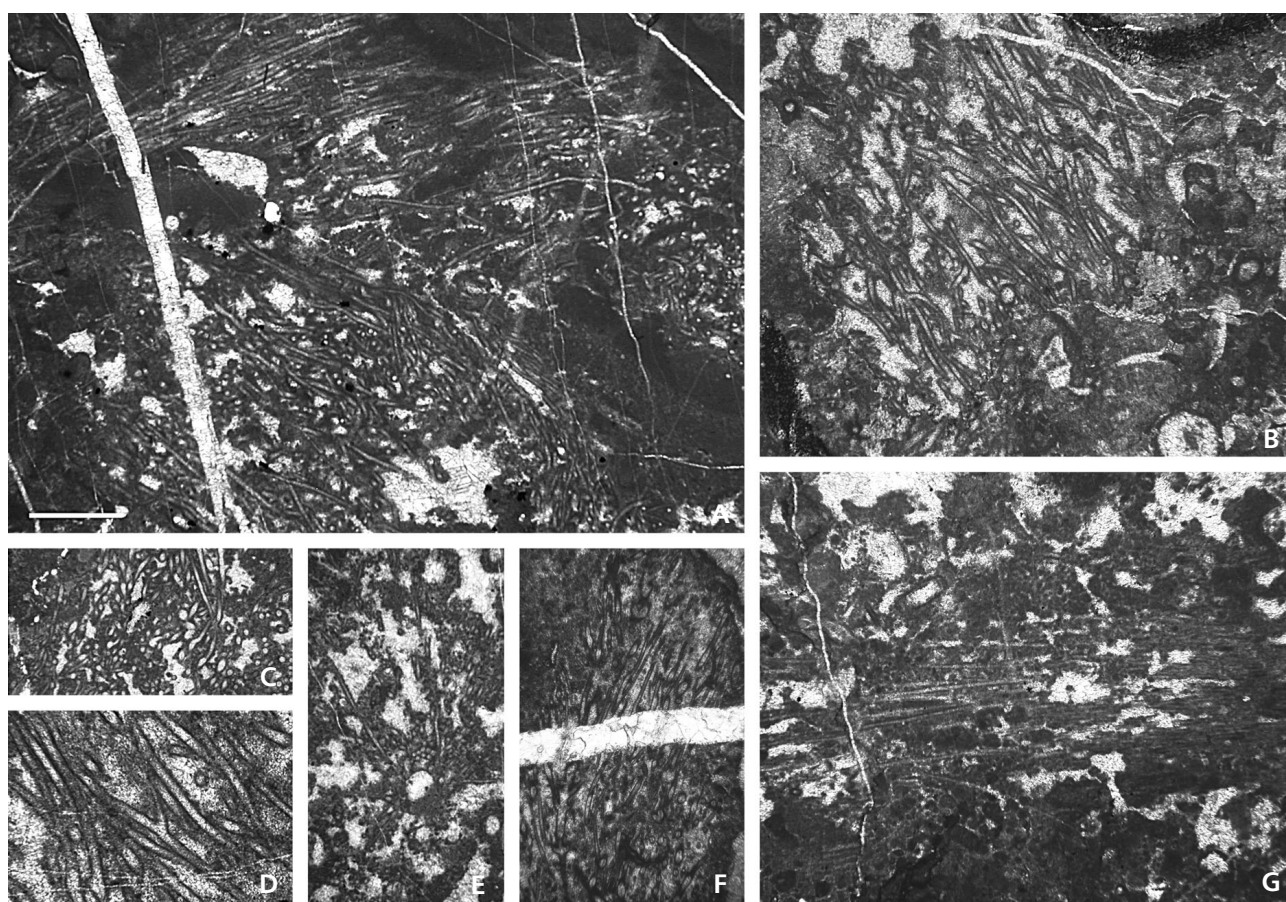
**Type species.** – *Mellporella anthracoporellaeformis* Rácz, 1964 (modified spelling for *anthracoporellaformis* nom. incorrect.).

**Description.** – Initially described as a seletonellacean more or less similar to *Anthracoporella* Pia, 1920 (Rácz 1964, Poncet 1986 and Mamet 1991), this taxon belongs most probably to another algal group.

**Occurrence.** – Late Bashkirian–Moscovian; Spain and Algeria.

### Genus *Mellporella*?

**Description.** – Subsegmented Udoteaceae with simple, elongate thallus; broad medullar zone not calcified; cortical zone with numerous, constituted by undulating, me-



**Figure 3.** Latest Viséan–earliest Serpukhovian *Ortonellopsis laxa* gen. et sp. nov. (scale bar = 1 mm, except for figures C, E = 0.5 mm and D = 0.25 mm). • A – paratype. Thin section MA-RM78, Roc de Murviel, earliest Serpukhovian. • B – paratype. Thin section MA-RM83, Roc de Murviel, earliest Serpukhovian. • C – paratype. Thin section MA-RM20, Roc de Murviel, latest Viséan. • D – holotype. Thin section MA-RM83, Roc de Murviel, earliest Serpukhovian. • E – paratype. Thin section MA-RM20, Roc de Murviel, latest Viséan. • F – paratype. Thin section Pc-4401, Roque Redonde, latest Viséan. • G – paratype. Thin section MA-LSV-2004, La Serre-vineyard, earliest Serpukhovian.

dium to broad threads, dichotomous, randomly arranged; white neomicrospartitized wall.

**Remarks.** – It is also possible that our material belongs to *Hikorocodium* Endo, 1951 *sensu lato*; first described as a codiale as indicated by its name but then assigned to the ischyrospongia or hypercalcified sponges (Vachard 1976, Termier *et al.* 1977, Senowbari-Daryan & Rigby 2007, Mamet & Prétat 2013). On the other hand, the recently described species *Hikorocodium rhenaensis* Mamet & Prétat, 2013 is most probably an algosponge *Sinus-tacheoides* or *Epistacheoides*.

**Occurrence.** – Early Serpukhovian of the Montagne Noire (this study); ?latest Viséan–Serpukhovian–Bashkirian of Algeria (Oubour Formation, Namurian A of Bechar Basin, E<sub>2</sub>-H ammonoid biozones of Tagnana Fm, early Bashkirian of upper Tagnana Fm, Westphalian A of Jebel Mezarif (Lemosquet & Poncet 1977, Poncet

1986, Sebbar & Lys 1989, Sebbar 1990, Sebbar & Mamet 1996); early Bashkirian of northern Spain (Vachard & Beckary 1991).

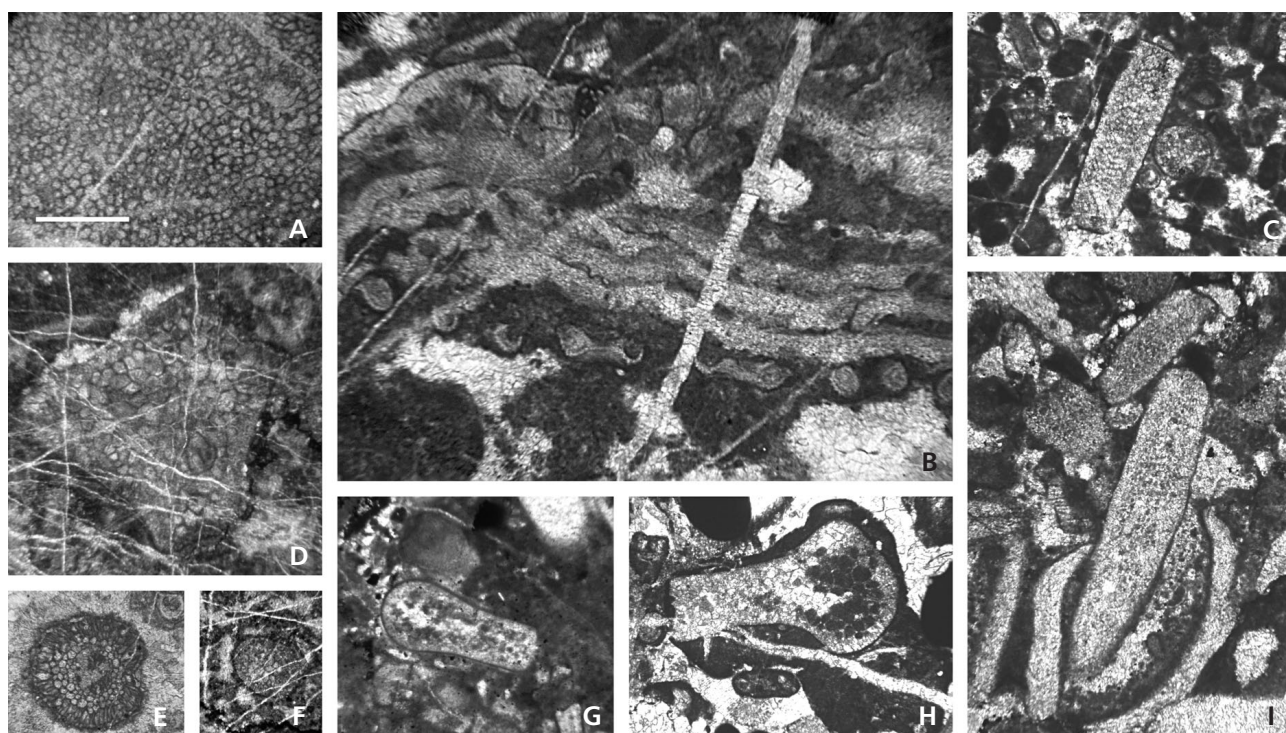
***Melporella?* aff. “magnum” (sensu Lemosquet & Poncet, 1977 non Endo, 1951)**

Figure 5A–D

Compare with

- 1977 *Anchicodium magnum*; Lemosquet & Poncet, p. 337, pl. 8, figs 1–6.
- 1986 *Melporella* (sic) *anthracoporellaformis*; Poncet, p. 188, pl. 1, figs 1–5.
- 1989 *Anchicodium magnum*; Sebbar & Lys, pl. 1, fig. 3.
- 1990 *Anchicodium magnum*; Sebbar, pl. 1, fig. 2.
- 1991 *Melporella anthracoporellaformis*; Vachard & Beckary, p. 323, pl. 1, figs 6, 7.





**Figure 4.** Late Viséan–early Serpukhovian Rhodophyta (scale bar = 0.5 mm). • A – *Anchisolenopora serrana* (Vachard & Aretz, 2004) gen. nov. Paratype, thin section MA-CC9A, Castelsec, early Serpukhovian. • B – *Archaeolithophyllum lamellosum* Wray, 1964, thin section MA-SP18, La Serre de Péret, early Serpukhovian. • C – *Neoprincipia fluegeli* (Vachard in Krainer & Vachard, 2002), thin section MA-LSI-2049, La Serre-vineyard, early Serpukhovian. • D – *Neoprincipia guadiatica* Cózar & Vachard, 2003, thin section MA-CC1, Castelsec, early Serpukhovian. • E – *Hortonella uttingi* Mamet, 1995, thin section MA-RR39, Roque Redonde, latest Viséan. • F – *Neoprincipia petschoriaeformis* Vachard & Aretz, 2004, thin section MA-CC1, Castelsec, early Serpukhovian. • G – *Neoprincipia claviformis* Vachard & Aretz, 2004, thin section, MA-LSIII-2021, La Serre-vineyard, early Serpukhovian. • H – *Neoprincipia guadiatica* Cózar & Vachard, 2003, thin section DV-126f, Japhet, late Viséan. • I – *Neoprincipia fluegeli* (Vachard in Krainer & Vachard, 2002), thin section MA-LSI-2044, La Serre-vineyard, early Serpukhovian.

1996 *Anchicodium* sp.; Sebbar & Mamet, pl. 2, figs 12, 13.

**Description.** – Maximal length = 8.800–12.450 mm, outer diameter = 3.000–5.000 mm, inner diameter = 1.700–2.700 mm, thickness of skeleton = 0.700–1.300 mm.

**Occurrence.** – Early Serpukhovian (Steshevian) of the Montagne Noire in La Serre de Péret (MA-SP-20, MA-SP-30).

Order ?Ulotrichales Borzi, 1895

Family Anatoliporaceae Vachard *et al.*, 1989  
emend. herein

**Synonym.** – Salpingoporellinae Bassoullet *et al.*, 1979 (*pars*; see Bassoullet *et al.* 1979, Roux 1985, Chuvashov *et al.* 1987, and Mamet 1991).

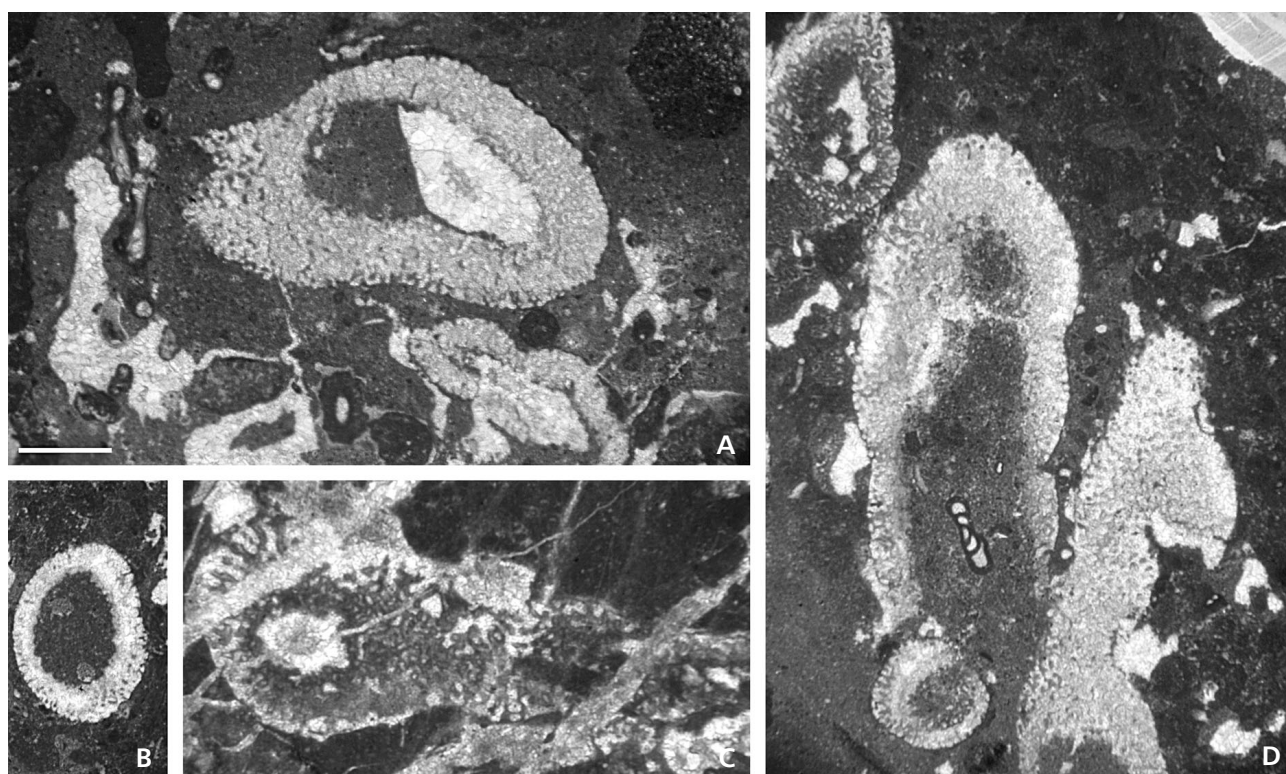
**Emended diagnosis.** – Attached colonies, composed of several thalli prostrate, domed, club-shaped to cylindrical. Central narrow cavity, or reduced to an enlargement at the

base of the laterals. Laterals numerous, aspondyl, phloio-phore with strong oblique insertion, rectilinear or with slight curvature. Wall microspartitized.

**Emended composition.** – *Anatolipora*; *Richella*; *Tegumen-tupecten* May, 1992; *Cylindrifolia* Brenckle & Groves, 1987.

**Comparison.** – The Anatoliporaceae differ from the true Dasycladales in the small central cavity, the numerous, oblique, aspondyl laterals. They differ from the Sele-tonellaceae in the numerous thalli assembled in a colony, and from the Vermiporellaceae Saltovskaya in Chuvashov *et al.*, 1987 in the small size, the less triangular ex-tremities, the colonial grouping, but the Vermiporella-ceae are the most similar group. Consequently, if admitted the assignment of *Vermiporella* Stolley, 1893, *ex Pia*, 1927, proposed by some authors (Kozłowski & Kazmierczak 1968, Emberger 1976), this family can be-long to the Ulotrichales. A possible Carboniferous ulot-richacean should be the late Viséan *Vermiporella sharty-mensis* Kulik, 1973; nevertheless, this latter species is





**Figure 5.** Early Serpukhovian *Melliporella*? aff. “magnum” [sensu Lemosquet & Poncet, 1977 non Endo, 1951] (scale bar = 2 mm), La Serre de Péret, early Serpukhovian. • A, B, D – thin section MA-SP20. • C – thin section MA-SP30.

difficult to interpret and might also belong to *Issinella*, *Crassikamaena* or *Luteotubulus* Vachard in Vachard et al., 1977.

**Remarks.** – The family Anatoliporaceae is emended herein in order to encompass (a) *Anatolipora*, (b) *Richella* which appears similar to *Anatolipora* in the organization of laterals, (c) *Tegumentupecten* which is morphologically similar to *Richella*; and (d) *Cylindrifolia* which is totally atypical for a dasycladale *bona fide*.

**Occurrence.** – Questionable in the Devonian and late Tournaisian. Brigantian–late Serpukhovian. Doubtful in the Pennsylvanian with *Anatolipora cantabriensis* Mamet & Villa, 2004.

### Genus *Anatolipora* Konishi, 1956 emend. herein

**Type species.** – *Anatolipora carbonica* Konishi, 1956.

**Emended diagnosis.** – Colonies composed of several club-shaped to cylindrical thalli. Each thallus has a narrow central cavity, numerous branches, aspondyl, phloiophore with strong oblique insertion and slight curvature. The wall is microsparitized and probably initially aragonitic.

**Composition.** – *Anatolipora carbonica*; *A. carbonica* sensu Buchroithner et al., 1980; *A. cantabriensis* Mamet & Villa, 2004; *A. macroporelloidea* Vachard & Cózar sp. nov.

**Remarks.** – Even if fragments of *Anatolipora* may be confused with dasycladales, entire colonies are completely different, and more similar to vermiporellacean algae; however, *Anatolipora* differs from these latter by the forms of laterals and smaller size of thalli. On the other hand, the genus *Richella* which seemed totally atypical among the algae, may be related with *Anatolipora*, by its type of laterals, although it differs by its attached growth.

**Occurrence.** – Latest Viséan (Brigantian) to late Serpukhovian (Arnsbergian). Japan, Montagne Noire, Pyrenees, Spain, Belgium, ?Algeria, Alaska, and Alberta (Mamet 1991).

### *Anatolipora carbonica* Konishi, 1956 emend. herein

Figure 6A–C, E, G–I

p. 1956 *Anatolipora carbonica* Konishi, pp. 121, 123, pl. 1, figs 1, 2?, 3, 4, 7, pl. 2, fig. 4; text-fig. 1a, b

- (nevertheless, the idealized euspondylity is misinterpreted); non pl. 1, figs 5, 6, 8, 9, pl. 2, figs 1–3, 5? (= *Windsoporella*).
- non 1961b *Anatolipora carbonica*; Endo, pp. 131–132, pl. 7, fig. 3 (= indeterminate dasycladale).
- 1971 *Anatolipora*; Kochansky-Devidé & Gusic, p. 86 (bottom, right), text-fig. 4.
- v. p. 1974b *Anatolipora carbonica*; Vachard, pp. 176–177, pl. 7, fig. 7 (non pl. 5, fig. 6 = *Cabrieropora pokornyi*).
- p. 1976 *Anatolipora carbonica*; Emberger, p. 18 (no illustration).
- v. 1977a *Anatolipora carbonica*; Vachard, p. 374, table 1 (no illustration).
- v. 1977b *Anatolipora carbonica*; Vachard, p. 134, pl. 1, fig. 9.
- non 1978 *Anatolipora* aff. *carbonica*; Mamet *et al.*, pp. 363–364, pl. 5, fig. 15 (a true dasyclad).
- non 1980 *Anatolipora carbonica*; Buchroithner *et al.*, pp. 22–23, pl. 4, figs 1, 2, 3?.
- 1980 *Nanopora anglica*; Buchroithner *et al.*, p. 25, pl. 5, fig. 5.
- 1985 *Anatolipora carbonica* Konishi (= *Anthracoporella bashkirica*). – Herbig & Mamet, pl. 1, fig. 8.
- 1988 *Anatolipora carbonica*; Deloffre, pl. 9, fig. 18.
- v. 1989 *Anatolipora carbonica*; Vachard *et al.*, p. 704, pl. 1, fig. 9 (with synonymy).
- 2002 *Anatolipora carbonica*; Mamet, p. 498, pl. 3, figs 4–10 (with synonymy).
- non 1989b *Anatolipora carbonica*; Nguyen Duc Tien, pl. 23, figs 6–9 (aspondyl and metaspondyl dasyclads).
- v. 1994 *Anatolipora carbonica*; Delvolvé *et al.*, p. 190, 193 (no illustration).
- ? 1997 *Richella incrustata*; Harris *et al.*, fig. 9, 25.
- v. 1998 *Anatolipora carbonica*; Delvolvé *et al.*, p. 366 (no illustration).
- non 1999 *Anatolipora carbonica*; Sebbar & Mamet, text-fig. 3.84, pl. 2, fig. 14 (a dasyclad because of the broad central cavity).
- p. 2000 *Anatolipora carbonica*; Granier & Grgasovic, pp. 9–10 (with synonymy) (no illustration).
- 2000 *Anatolipora* sp.; Sebbar, pl. 1, fig. 8.
- 2008 *Anatolipora carbonica*; Pille, p. 27, pl. 6, figs 1–12.

**Emended diagnosis.** – *Anatolipora* with up to seven bifurcated thalli, exhibiting a narrow central cavity and numerous simple laterals which are acrophore, gently curved, regularly alternating and separated by a relatively broad interlateral calcified space.

**Description.** – Maximal length = 4.000 mm, outer diameter = 0.300–0.610 mm, inner diameter = 0.060–0.130 mm, thickness of skeleton = 0.150–0.260 mm, proximal diameter of laterals = 0.015–0.020 mm, distal diameter of laterals = 0.025–0.033 mm.

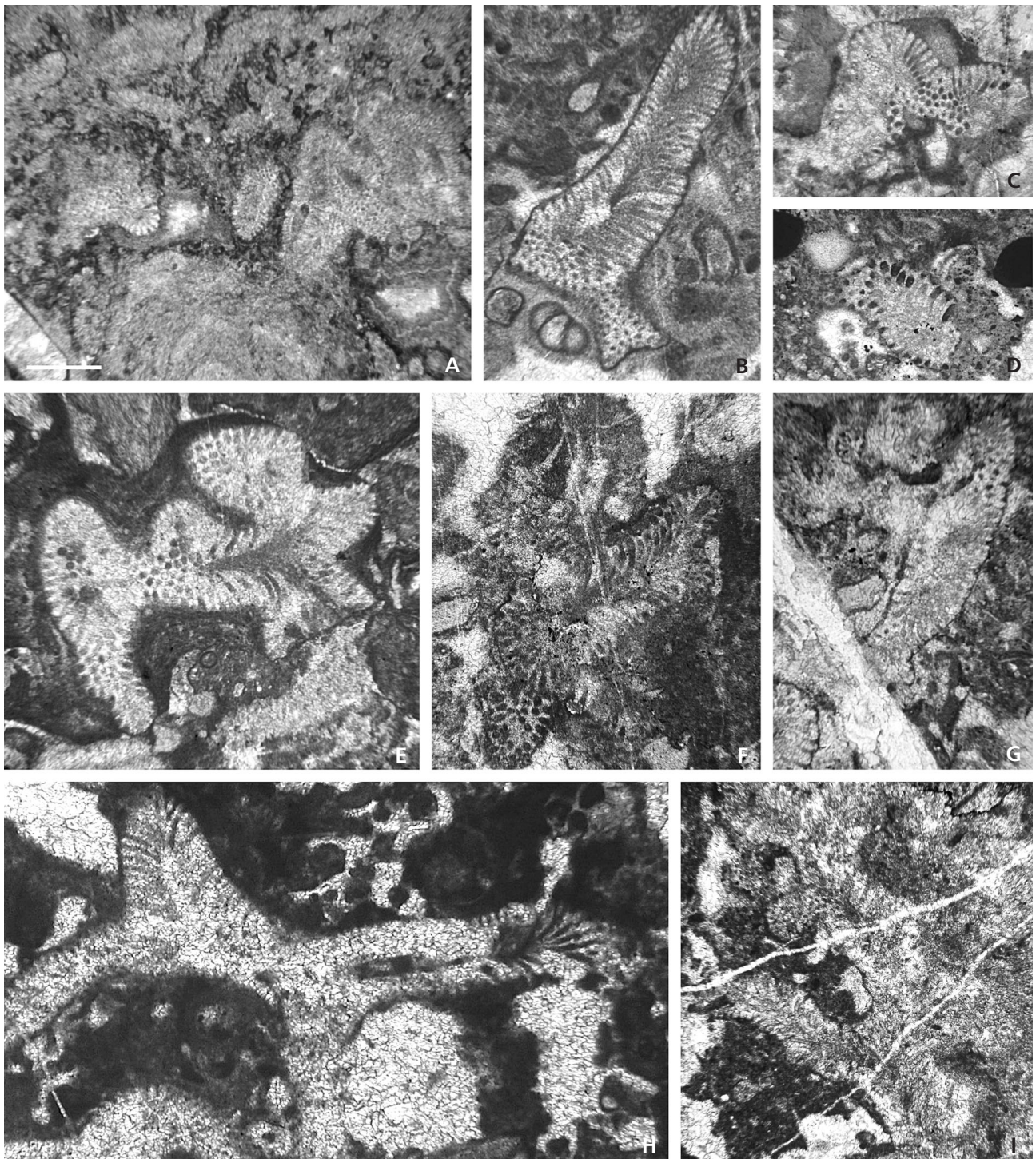
**Remarks.** – Paradoxically, *Anatolipora carbonica* possessed two “holotypes”. The first one was a relatively atypical transverse section illustrated by Konishi (1956, pl. 1, fig. 2); the second one (pl. 1, fig. 4) was an axial section. This latter corresponds to the thallus reconstruction of Konishi (1956, p. 120, text-fig. 1) and to the specimens generally assigned to *Anatolipora* by Mamet & Rudloff (1972), Vachard (1977b), and Herbig & Mamet (1985). Hence, we designate here, as unique type (lectotype) and generotype, the pl. 1, fig. 4 of Konishi (1956). Furthermore, a part of the type material corresponds to sections of *Windsoporella* Mamet & Rudloff, 1972 emend. Vachard, 1980 (e.g., pl. 1, figs 5, 6, 8, 9, pl. 2, figs 1–3).

On the other hand, the illustrations of Homann (1972), first revised by Vachard *et al.* (1989), can be re-interpreted as follows: The fig. 24 is a small *Mizzia* sp., fig. 45 is a cribrate aperture of *Climacammina* sp., and fig. 54 is a polyaxone sponge spicule.

Furthermore, Herbig & Mamet (1985, pl. 1, fig. 8) have suggested that *Anatolipora carbonica* Konishi could be synonymized with *Anthracoporella bashkirica* Kulik, 1973. In our opinion, these taxa differ; nevertheless, *Anthracoporella bashkirica* is possibly an ulotrichale. Similarly, the specimens of *Anatolipora carbonica* of Buchroithner *et al.* (1980) correspond to another ulotrichale taxon; however, true *Anatolipora carbonica* are present in the assemblages described by Buchroithner *et al.* (1980), although erroneously designated as *Nanopora anglica*.

**Occurrence.** – As for the genus; in the Montagne Noire, Mikhailovian–Steshevian (late Viséan–early Serpukhovian = foraminiferal biozones A to G): Castelsec (Pc-4523, Pc-4537, MA-11.9.1.Quer, MA-11.9.1. Längs, MA11.9.3, MA11.10); Roc du Cayla (Pc-4578, Pc-4584, Pc-4585, Pc-4603, MA-12.18, MA-12.22, DV84A, DV465B); Roque Redonde (MA-RR2, MA-RR27, MA-RR31, MA-RR35, MA-RR51, MA-RR52, MA-RR53, MA-RR54, MA-RR55, MA-RR56, MA-RR57, MA-RR59, MA-RR60, MA-RR62, MA-RR63, MA-RR69, MA-RR71, MA-RR73, MA-RR74, MA-RR76?, MA-RR79, MA-RR84?, MA-RR88); La Boutinelle (Pc-4656, Pc-4653, Pc-4649, MA-Bou25.5, MA-Bou25.7, MA-Bou25.8, MA-Bou25.9, MA-Bou25.9B, MA-Bou25.12, MA-Bou25.14, MA-Bou25.18, MA-Bou25.19); Tiberet (ML.FSL.TIB); Château-Vailhan (Pc-4709, Pc-4721, Pc-4724, Pc-4725, Pc-4734, Pc-4738, Pc-4740, Pc-4741, Pc-4742, Pc-4743, Pc-4744, DV232A); Roc de Murviel (MA-8, MA-9, MA-21, MA-26, MA-50, MA-70, MA-73.2, MA-33.82, MA-33.83, MA-330.4, MA-330.5, MA330.11, Pc-4462, Pc-4913, DV251B); La Serre de Péret (MA-SP.18); northern slope of Les Batailles hill (DV612A, DV611B). Late Serpukhovian in the Pyrenees: Ardengost (MFP.AH81.1).





**Figure 6.** Late Viséan–early Serpukhovian Anatoliporaceae (scale bar = 0.5 mm). • A–C, E, G–I – *Anatolipora carbonica* Konishi, 1956 emend. herein. • A – thin section MA-CC2, Castelsec, early Serpukhovian. • B – thin section MA-RR31, Roque Redonde, latest Viséan. • C – thin section MA-RM36, Roc de Murviel, latest Viséan. • E – thin section MA-33-83, Roc de Murviel, latest Viséan. • G – thin section MA-330-5, Roc de Murviel, early Serpukhovian. • H – thin section MA-11-10, Castelsec, early Serpukhovian. • I – thin section PC4735, Château-Vailhan, latest Viséan. • D, F – *Anatolipora macroporelloidea* sp. nov. • D – paratype. Thin section DV-605A (USTL 1307), Mounio, late Viséan. • F – holotype. Thin section DV-609 (USTL 1308), Les Batailles, late Viséan.

**Anatolipora macroporelloidea Vachard & Cózar sp. nov.**

Figure 6D, F

2008 *Anatolipora macroporelloidea* Pille, p. 28, pl. 6, figs 13–18 (nomen nudum).

**Etymology.** – Comparable to the seletonellacean dasyclad *Macroporella* Pia, 1912.

**Locus typicus.** – Northern slope of Les Batailles hill, near Cabrières village (Hérault, France).

**Stratum typicum.** – Venevian.

**Holotype.** – Fig. 6F (sample DV609); collection number USTL 1308.

**Type material.** – Approximately 60 specimens (in 30 thin sections).

**Diagnosis.** – *Anatolipora* characterized by wide laterals and thinner interlateral calcification.

**Description.** – Maximal length = 2.220 mm, outer diameter = 0.315–0.500 mm, inner diameter = 0.075–0.130 mm, thickness of skeleton = 0.120–0.175 mm, proximal and distal diameters of laterals = 0.055–0.075 mm.

**Repository of the types.** – Collection of Palaeontology of the Lille University (numbers 1307–1308).

**Comparison.** – It differs from *A. carbonica* by the larger size of the colonies and the broader laterals.

**Remarks.** – *Anatolipora macroporelloidea*, although rare in the Montagne Noire, could represent one of the biomarkers of the latest Viséan–earliest Serpukhovian boundary interval, because of its association with (a) the foraminiferal assemblage of Les Batailles hill, and (b) with *Neoprincipia petschoriaeformis* Vachard & Aretz, 2004 in the basal flysch levels of Mounio-Cabrières.

**Occurrence.** – Venevian–Steshevian of the Montagne Noire (foraminiferal biozones D to G): La Boutinelle (MA-Bou.25.9b, MA-Bou.25.19), Castelsec (Pc-4522, Pc-4545, Pc-4560, MA-11.1.9p), Roc du Cayla (Pc-4582, Pc-4586, MA-12.18, MA-12.22), Château-Vailhan (Pc-4730, Pc-4735, Pc-4737, Pc-4740, Pc-4741, Pc-4742, Pc-4743, Pc-4744), Roque Redonde (Pc-4418, Pc-4412, Pc-4411, Pc-4404, Pc-4398, Pc-4397, MA-RR52), Roc de Murviel (MA-RM-36, MA-33.82, MA-33.83, MA-330.05), northern slope of Les Batailles hill (DV612A), and Mounio-Cabrières (DV605B).

Class Chlorophyceae Kützing, 1843

Order Dasycladales Pascher, 1931

Family Seletonellaceae (Kordé, 1950 nom. transl. Kordé, 1973) *ex* Bassoullet *et al.*, 1979

**Description.** – This family corresponds to the aspondyl dasycladales (*e.g.*, Bassoullet *et al.* 1979; Roux 1985; De-loffre 1987, 1988).

**Occurrence.** – ?Cambrian–Ordovician–Early Cretaceous; cosmopolitan.

Tribe Epimastoporeae Vachard, Krainer & Lucas, 2012

**Description.** – Large fragments of cylindrical, club-shaped or most commonly subspherical dasycladales. Broad central cavity and relatively thin walls. Lateral simple, numerous, aspondyl but almost euspondyl, and having some shapes relatively uncommon among the dasycladales; *e.g.*, prismatic, “clepsydral” (see Baratollo *et al.* 1993), ellipsoidal sometimes very inflated in the centre, and dumbbell-like (perhaps in relation with a unknown mode of reproduction). They communicate with the exterior by a small pore or apparently have no preserved connections (*Globuliferoporella*). Outer and inner surfaces generally smooth but intusannulations exist in *Paraepimastopora*. Wall whitish microsparitized, probably initially aragonitic.

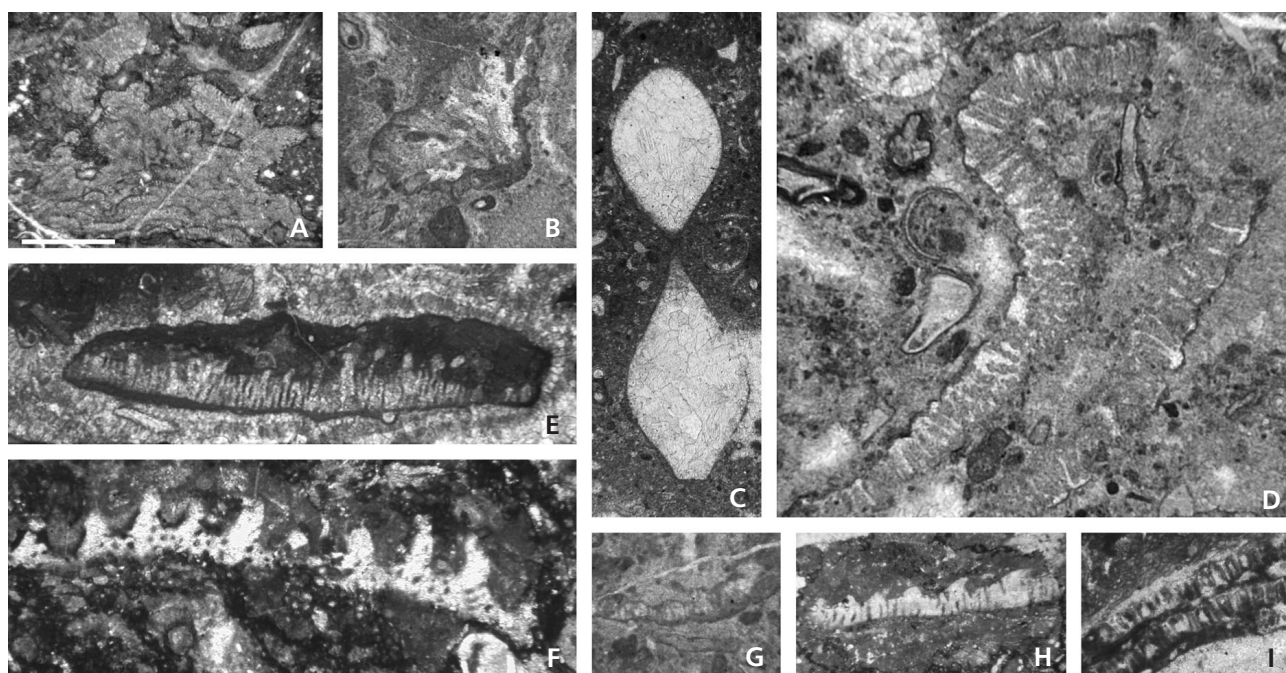
**Composition.** – *Epimastopora* (Pia, 1922) Kochansky-Devidé & Herak, 1960; *Kahaganella* Falahatgar *et al.*, 2015; *Palaepimastoporella* Cózar & Vachard, 2004; *Paraepimastopora* Roux, 1979 emend. Krainer & Vachard, 2002; “*Epimastopora*” in the sense of Rácz (1964, 1966; with *E. bodoniensis* Rácz, 1964; *E. comesobresensis* Rácz, 1966, *E. rolloensis* Rácz, 1964); *Globuliferoporella* Chuvashov, 1974; ?*Borisovella* Ivanova, 1988; ?*Sphenoporella* Chuvashov, 1974; and ?“*Embergerella*” Güvenç, 1972 pre-occupied (see Cózar & Vachard 2004). See also the descriptions of the subtribe Epimastoporellinae Cózar & Vachard (2004) and tribe Epimastoporeae Vachard *et al.* (2012).

**Occurrence.** – Late Tournaisian–Late Permian; cosmopolitan in the Late Pennsylvanian–Early Permian, or otherwise Palaeotethyan.

**Genus *Paraepimastopora* Roux, 1979 emend. Krainer & Vachard, 2002**

**Synonyms.** – *Epimastopora* “Pia, 1922” (*pars*); *Anthracoporella* Pia, 1920 (*pars*), *Anchicodium* Johnson, 1946 (*pars*).





**Figure 7.** Late Viséan–early Serpukhovian Chlorophyta (scale bar = 1 mm). • A – *Richella incrustata* Mamet & Roux in Mamet *et al.*, 1987; thin section MA-CC2, Castelsec, early Serpukhovian. • B – *Orthriosiphon?* sp., thin section MA-RR73, Roque Redonde, early Serpukhovian. • C – *Saccaminopsis fusulinaeformis* McCoy, 1849, thin section DV-325, Roc de Loup-Vailhan, late Viséan. • D – *Palaepimastoporella espielensis* Cózar & Vachard, 2004, thin section MA-RR81, Roque Redonde, early Serpukhovian. • E–H – *Paraepimastopora somervillei* sp. nov. • E – holotype. Thin section MA.BOU25.8, La Boutinelle, latest Viséan. • F – paratype. Thin section MA-LS Feldweg 10, La Serre-vineyard, early Serpukhovian. • G – paratype. Thin section MA-RR73, Roque Redonde, early Serpukhovian. • H – paratype. Thin section MA-LS Feldweg 33, La Serre-vineyard, early Serpukhovian. • I – *Palaepimastoporella espielensis* Cózar & Vachard, 2004, thin section MA-LS Feldweg 36, La Serre-vineyard, early Serpukhovian.

*Type species.* – *Epimastopora kansasensis* Johnson, 1946.

*Diagnosis.* – Thallus probably cylindrical or club-shaped with rather large central cavity, poorly calcified and often broken. Skeleton perforated by numerous, thin, aspondyl, simple, acrophore laterals, closely spaced, and with relatively thickly calcified interpores. Regular intusannulations are generally well developed.

*Composition.* – *Epimastopora kansasensis* Johnson, 1946, *E. jewetti* Johnson, 1946; *E. kanumai* Endo in Endo & Kanuma, 1954; *E. lateinterporosa* Endo, 1961b; *E. longituba* Endo, 1957; *E. malaysiana* Elliott, 1968b; *E. regularis* Johnson, 1946; *E. urtazymensis* Chuvashov & Anfimov, 1988; *Paraepimastopora noetschensis* Krainer & Vachard, 2002; *P. grandis* (Chuvashov & Anfimov) *sensu* Mamet & Prétat, 2010; *P. peytoni* Mamet & Prétat, 2013; *P. somervillei* sp. nov.

*Remarks.* – Contrary to Granier & Deloffre (1995), *Paraepimastopora* and *Tauridium* are distinct because *Tauridium* Güvenc, 1966 is only a stage of preservation of *Permocalculus* as well as *Dzhulfanella* or *Pyrulites* (Vachard *et al.* 2005). Furthermore, *Paraepimastopora sensu* Brenckle & Groves (1987, fig. 12.4) are misinterpreted and more pro-

bably corresponds to a tangential section of *Cylindrifolia*. In contrast, “*Orthriosiphon*” of these authors (Brenckle & Groves 1987, fig. 12.16–17) are possibly epimastoporaceans similar to *Kahanagella* (see Falahatgar *et al.* 2015).

*Occurrence.* – Late Asbian–early Serpukhovian of Spain (Sánchez-Chico *et al.* 1995; Cózar & Somerville 2005b, p. 80). Early Brigantian of central Morocco (unpublished data). Brigantian of Ireland (Cózar & Somerville 2005b, text-fig. 3). Venevian–early Serpukhovian of southern France (this study) and Oklahoma, U.S.A. (Groves 1983, Mamet & Prétat 2013). The acme of this genus occurs during the Pennsylvanian–Cisuralian; it disappears probably in the Guadalupian. Northwestern Palaeotethyan during the early Mississippian; then, it becomes cosmopolitan.

### ***Paraepimastopora somervillei* Vachard & Cózar sp. nov.**

Figure 7E–H

- ?1973 *Orthriosiphon?*. – Maslov, pl. 2, fig. 6 (or other species of the genus).
- ?p. 1974 *Zaporella?* sp. – Rich, pl. 1, fig. 11 (non fig. 14 = *Richella*).

- ?1995 *Paraepimastopora* sp. – Sánchez-Chico *et al.*, p. 73, pl. 3, fig. 12.
- ?1996 *Paraepimastopora* sp. – Sebbar & Mamet, pl. 2, fig. 4.
- ?1999 *Paraepimastopora* sp. – Sebbar & Mamet, pl. 1, fig. 8.
- ?2003 *Paraepimastopora* sp. – Mamet & Misik, fig. 3.1–3.
- v. 2004 *Paraepimastopora* sp. – Vachard & Aretz, p. 652, fig. 8.5.
- ?v. 2004 *Paraepimastopora* sp. – Cózár, text-fig. 3, p. 371, text-fig. 4, p. 372 (no illustration).
- v. 2004a *Paraepimastopora* sp. – Cózár & Vachard, fig. 4.11.
- v. 2004 *Paraepimastopora?* sp. – Cózár & Somerville, p. 45, text-fig. 3, p. 47, text-figs 6, 8, p. 48, text-fig. 9, p. 49, figs 13.4, 13.7, 14.28.
- v. ?2005 *Paraepimastopora* sp. – Karim *et al.*, fig. 3H.
- v. 2005 *Paraepimastopora* (?) sp. – Cózár, text-fig. 4, p. 409, fig. 7.19.
- v. 2005a *Paraepimastopora?* sp. – Cózár & Somerville, p. 25, text-fig. 16.
- v. 2005b “*Paraepimastopora*” sp. – Cózár & Somerville, pl. 1, fig. 15.
- v. 2005c *Paraepimastopora* sp. – Cózár & Somerville, fig. 4.9.
- v. 2008 *Paraepimastopora cozarii* Pille, p. 34, pl. 9, figs 3–5 (nomen nudum).

**Etymology.** – Dedicated to Prof. Ian Somerville (Dublin), for his work in Early Carboniferous micropalaeontology and biostratigraphy.

**Locus typicus.** – La Boutinelle (Hérault, France).

**Stratum typicum.** – Venevian.

**Holotype.** – Fig. 7E (sample MA.BOU25.8); Collection M. Aretz, Toulouse.

**Diagnosis.** – Small species, with small diameter and intusannulation not hollow.

**Description.** – Maximal length of thallus = 5.000–6.000 mm, wall thickness = 0.600 mm, diameter of pores = 0.050 mm, interpore space = 0.150 mm.

**Type material.** – 47 specimens.

**Repository of the types.** – Collection M. Aretz, Toulouse.

**Comparison.** – The new species differs from *P. noetschen-sis* Krainer & Vachard, 2002 in the dimensions and the not hollow intusannulations and from *P. peytoni* Mamet & Prétat, 2013, very poorly described and illustrated, by its broader pores.

**Occurrence.** – Late Asbian–early Serpukhovian of Spain, Brigantian of Ireland, Serpukhovian of Bechar Basin (Algeria), Asbian/Brigantian of central Morocco, early Brigantian of northern England and Brigantian of the Slovak Republic. Venevian of La Boutinelle (MA.BOU25.8) and slope of Batailles hill (DV607D). Latest Viséan (Venevian)–early Serpukhovian (Steshevian) (foraminiferal zones D to G) of La Serre-vineyard (MA.LS.Feldweg10) (see also Vachard & Aretz 2004: GIK 1801; GIK1814).

Family Diploporaceae Pia, 1920 nom. transl. Shuysky (1987) *non* Deloffre (1987) *nec* Deloffre (1988) emend. Pille & Vachard, 2011

**Diagnosis.** – Cylindrical to segmented metaspondyl dasycladales.

**Composition.** – During the Palaeozoic, the family Diploporaceae encompasses three tribes: Velebitelleae Vachard, 1977b, Albertaporelleae Güvenç, 1979 nomen transl. Deloffre, 1988, and Diploporeae Pia, 1920 nomen transl. Güvenç, 1979. This number is probably greater due to: 1) the little knowledge of the uppermost Devonian–lowermost Mississippian Diploporaceae, despite of the numerous studies in *e.g.*, Belgium, Ukraine, European Russia and Siberia; 2) the great differentiation of the diploporean genera during the Mesozoic, the Palaeozoic ancestors of which are not yet well known.

Like new diplopore dasycladales from the Montagne Noire were recently published by Pille & Vachard (2011), only the status of two tribes is revised herein, Velebitelleae and Borladelleae trib. nov.

**Occurrence.** – Early Devonian to Triassic, generally confined to the Tethys and Ural oceans; rarely in the shelves of the North American craton.

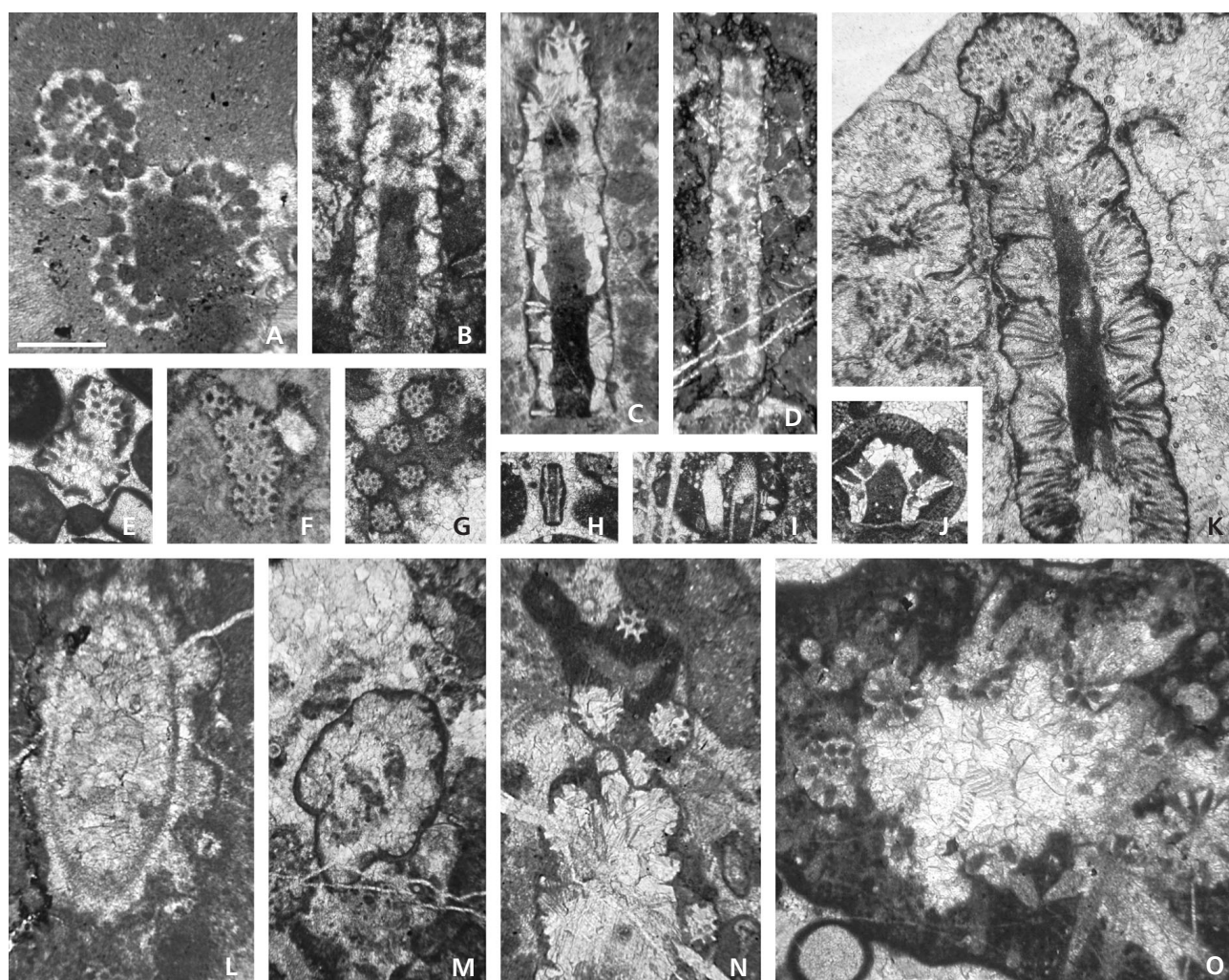
Tribe Velebitelleae Vachard, 1977b emend. Pille & Vachard, 2011

**Diagnosis.** – Vestibuled and articulated Diploporaceae, with acrophore, phloiophore or vesiculifer laterals, and with cylindrical to subspherical articles more or less individualized.

**Composition.** – Two subtribes: (1) Velebitellinae Vachard, 1977b nom. transl. Bassoullet *et al.*, 1979; (2) Kulikiinae Pille & Vachard, 2011.

**Occurrence.** – Early Devonian to Late Permian, generally confined to the Tethys and Ural oceans; rarely described in the coeval shelves of the North American craton.





**Figure 8.** Late Viséan–early Serpukhovian dasycladales (scale bar = 0.5 mm except for figure K = 1 mm). • A – *Kulikia sphaerica* Golubtsov, 1961, thin section MA-RR15, Roque Redonde, latest Viséan. • B – *Windsoporella solida* Pille & Vachard, 2011, thin section Pc-4549, Castelsec, early Serpukhovian. • C – *Windsoporella tulayae* (Chanton-Güvenç, 1972b) ex Pille & Vachard, 2011, thin section MA-RM37, Roc de Murviel, latest Viséan. • D – *Guadiatella heraldica* Pille & Vachard, 2011, thin section MA-Feldweg 10, La Serre-vineyard, early Serpukhovian. • E – *Cabrieropora pokorny* Mamet & Roux, 1975a, thin section DV-856, Japhet, late Viséan. • F – *Cabrieropora pokorny* Mamet & Roux, 1975a, thin section MA-CC2, Castelsec, early Serpukhovian. • G – *Cabrieroporellopsis inopinatus* Pille & Vachard, 2011, thin section Pc-4556, Castelsec, early Serpukhovian. • H – *Windsoporella pareyni* (Mamet & Roux, 1975a), thin section Pc-4702, La Serre de Péret, early Serpukhovian. • I – *Nanopora anglica* Wood, 1964, thin section DV-126g, Japhet, late Viséan. • J – *Windsoporella longirostris* Pille & Vachard, 2011, thin section Pc-4702, La Serre de Péret, early Serpukhovian. • K – *Eovelebitella occitanica* Vachard, 1974a, thin section Pc-4557, Castelsec, early Serpukhovian. • L – *Murvielopora aretzii* Pille & Vachard, 2011, thin section MA-33-53, Roc de Murviel, latest Viséan. • M – *Borladella* cf. *alternans* Cózar et al., 2007, thin section MA-RM36, Roc de Murviel, latest Viséan. • N – *Cabrieroporellopsis inopinatus* Pille & Vachard, 2011, thin section MA-RM37, Roc de Murviel, latest Viséan. • O – *Cabrieroporellopsis inopinatus* Pille & Vachard, 2011, thin section DV-857(3), Japhet, late Viséan.

Tribe Borladelleae Vachard & Cózar, 2011 trib. nov.

**Diagnosis.** – Vestibuled and articulated Diploporaceae, with acrophore and phloioophore laterals, and with articles moderately to strongly individualized (strongly prominent in the Borladellinae).

**Composition.** – Two subtribes: (1) Cabrieroporinae Pille & Vachard, 2011; (2) Borladellinae Pille & Vachard, 2011.

**Remarks.** – The centre of speciation of this tribe is very probably located in southern France and Spain, due its great genus differentiation in this area. However, this very poorly known and distributed tribe has possibly a larger geographical distribution, because a species was encountered as far as Alaska (Mamet & Prétat 2010), without any transitional area known between these two extremities. Until now in the Montagne Noire, the tribe included two endemic genera, *Murvielipora* Pille & Vachard, 2011 (Fig. 8L) and *Cabrieroporellopsis* Pille & Vachard, 2011

(here Fig. 8G, N, O), but during this study, rare specimens of *Borladella* Cózar *et al.*, 2007 have been found (Fig. 8M).

**Occurrence.** – Latest Viséan–Bashkirian; southern Spain, southern France, and Alaska.

Family ?Polyphysaceae Kützing, 1843  
Tribe indet.

**Genus *Neoradiosphaeroporella* Cózar & Vachard gen. nov.**

**Type species.** – *Neoradiosphaeroporella aprica* Cózar & Vachard sp. nov.

**Etymology.** – Greek neo, new, because younger than *Radiosphaerella*, similar genus.

**Diagnosis.** – Possible sporangia filled with spherical spores tangentially jointed together.

**Composition.** – Monospecific.

**Comparison.** – There are generally four interpretations of the groups of small spheres more or less linked by a microspartic cement: 1) sporangia of Polyphysaceae (especially for the Mesozoic and Cenozoic forms); 2) calcification of the central cavity of endospore genera (*e.g.*, *Aciculella* Pia, 1930 *non* 1927 and “*Atractyliopsis*” *sensu* Rich, 1974, Mamet & Roux 1975a, and Devuyst 2006, *non* Pia 1937 *ex* Accordi, 1956), 3) vesicular dasycladales with large distal part and short proximal part (*e.g.*, *Holosporella* Pia, 1930; *Barrettiporella* Granier & Hofmann, 2002), 4) undeterminate groups of spherical bodies (*e.g.*, *Radiosphaeroporella* Mamet & Boulvain, 1992, *Ningbingellina* Mamet, 1998, *Ningbingellina sensu* Devuyst, 2006, figs 4.26.8–12, 23, *Floritheca* Gaillot & Vachard, 2007, *Aphanocapsites* Maslov *sensu* Mamet & Prétat, 2013). Nevertheless, some of these groups of spheres do not belong to sporangia but to thallus of Epimastoporaceae (probably *Palaepimastoporella*); *e.g.*, *Atractyliopsis* sp. *sensu* Mamet & Rudloff, 1972, pl. 3, fig. 16 only (non pl. 3, figs 15, 17); *Atractyliopsis* sp. *sensu* Mamet, 1976, pl. 4, fig. 1; *Atractyliopsis cumberlandensis* Rich, 1974 *sensu* Skompski, 1986, pp. 259–260, pl. 2, figs 1, 6; and *Coelosporella*? sp. *sensu* Vachard & Tahiri, 1991, pl. 4, fig. 19. On the other hand, some other “*Atractyliopsis*”, or “*Koninckopora*” and “*Coelosporella*” (see Saltovskaya 1974, Berchenko 1981, Chuvashov *et al.* 1987, Brenckle & Groves 1987, Mamet & Prétat 2010) most probably belong to a genus more or less related with *Eokoninckopora* Saltovskaya, 1984, which is neither an old *Koninckopora* (as etymologically suggested) nor even a dasycladale.

**Remarks.** – Usually, the isolated spheres of *Neoradiosphaeroporella* are covered by a thin layer of sparry calcite. The hollow of the uncalcified stem was only observed in three specimens (Fig. 9B, D, E), showing that the cortex seems to be composed of two rows of spheres. Some specimens show that the outer, thin layer of sparite is composed of a closer fibrous calcite rim (perhaps more resistant to recrystallization), growing in flat and polygonal sutures. The fibrous rims are usually preserved (probably calcitic in origin), but material between the rims is usually recrystallized, even micritized.

In *Neoradiosphaeroporella*, totally recrystallized cortices show a polygonal shape, and a different material can occur between the spherical rims and the rest of the cortex, that is easily recrystallized or micritized. Moreover, the arrangement of the spheres is more irregular, so oblique sections can show spheres of several diameters. The presence of two rows of spheres in *Neoradiosphaeroporella* is suggested in the oblique sections of more or less an entire thallus. Other facts that suggest the presence of this double row is the scarcity of sections in which the central hole is observed. The thickness of the microgranular and fibrous rims are always uniform around the spheres. However, small fragments of thallus usually show an irregular arrangement of the spheres and rarely alternate, coalescent rows of spheres. These fragments are interpreted as transverse sections of thallus, showing the two rows of spheres.

**Occurrence.** – The first unquestionable Polyphysaceae exist in the Serpukhovian of Tindouf (Cózar *et al.* 2014); consequently, *Neoradiosphaeroporella* gen. nov., which appears as early as the latest Viséan, is possibly a transitional stage to this family. However, B. Granier (pers. comm., May 2016) considers that Polyphysaceae did not exist during the Palaeozoic, and that this family only appeared in the Mesozoic. *Neoradiosphaeroporella* is currently only known in southern France and southern Spain.

***Neoradiosphaeroporella aprica* Cózar & Vachard sp. nov.**

Figure 9A–G

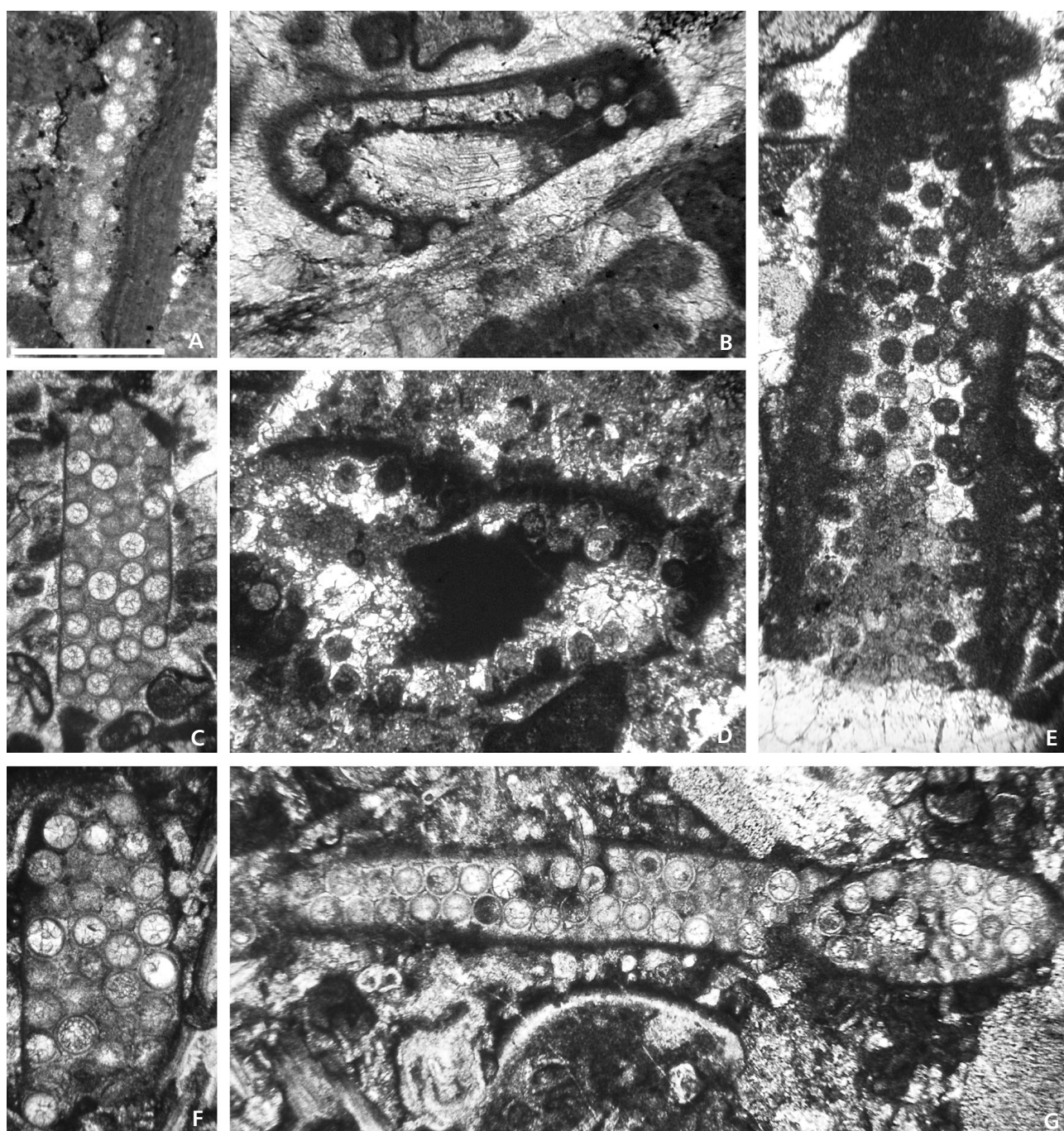
v. 2007 cf. *Radiosphaeroporella*. – Cózar *et al.*, p. 101, text-fig. 3.

?2010 *Atractyliopsis lastensis* Mamet & Roux, 1978 (*sic*; in reality, this species was described by Pia 1937). – Mamet & Prétat, pl. 3, figs 6, 7 (but numbered 7, 8 on the plate).

**Etymology.** – Latin *apricus*, sunny, because known from the most sunny areas of southern France and Spain.

**Locus typicus.** – Peñarroya 4 section, SW Spain (Cózar & Rodríguez 1999a).





**Figure 9.** *Neoradiosphaeroporella aprica* gen. et sp. nov., late Viséan (scale bar = 0.5 mm). • A – thin section MA-RM6, Roc de Murviel. • B – thin section MA-RM9, Roc de Murviel. • C – paratype. Thin section Pc-SPL1/2e, Sierra Palacios. • D – thin section Pc-PÑR4/2b, Peñarroya 4. • E – holotype. Thin section Pc-PÑR4/2a, Peñarroya 4. • F, G – paratypes. Thin section Pc-SPL1/5c, Sierra Palacios.

*Stratum typicum.* – PÑR4/2a, near base of the level 2 in Peñarroya 4, early Asbian.

*Holotype.* – Fig. 9E, specimen DPM-Pc-PÑR4/2a.

*Diagnosis.* – Conical, elongate and irregular poorly to strongly calcified central cavity in which are located two ir-

regularly arranged rows of calcified spheres (cysts?; endospore reproduction?). Contacts between the spheres with a differentiated wall, an inner microgranular layer, an intermediate fibrous rim of calcite, and outer fibrous calcite layer with flat and sharp coalescent sutures between the spheres. Wall generally dark-microgranular rarely recrystallized into neosparite.

**Description.** – Only two specimens show slight oblique sections of the thallus, and most specimens are lateral sections or fragments of the cortex. Maximum length of the thallus is from 1.750 mm to 2.650 mm, and the small fragments range from 0.500 mm to 1.700 mm. The number of cysts in tangential section of the thallus is difficult to estimate. The inner diameter of the cysts varies, but it seems to depend on the orientation. In more homogenous sections, the cysts range from 0.070 mm to 0.120 mm, the wall in the cortex is composed of three different layers: a thinner microgranular layer (0.002–0.003 mm), disposed around the cysts; a well preserved intermediate fibrous layer, covering the microgranular layer and with an uniform thickness around (0.010–0.020 mm); and an outer layer that may be recrystallized, micritized or rarely preserved as fibrous. In the latter case, the fibres have a coalescent growth, and the outer periphery of the cells are polygonalized. The outer surface of the cortex is slightly convex and regular; the inner surface of the cortex is strongly irregular and depends on the arrangement and size of the cysts in the internal row. No apertures have been observed in the cysts, but they seem to exist because many cysts have been preserved with micrite infilling (maybe as fine perforations crossing through the cortex). The cysts are rarely in alternate paired arrangements, and they usually show a slightly random arrangement.

**Type material.** – 28 oblique sections from southern Spain and three specimens from the Montagne Noire.

**Repository of the types.** – Department of Palaeontology (P. Cózar Ph.D. collection), Facultad de Ciencias Geológicas, Universidad Complutense de Madrid.

**Comparison.** – Differs from “*Atractyliopsis*” *sensu* Rich, 1974 and Mamet & Roux 1975a and 1978 by shorter fragments and more regularly arranged, small, spherical cysts; from true *Atractyliopsis* (Pia, 1937) *ex* Accordi, 1956 emend. Pratulon, 1963 by a stronger calcification of the sporanges, and cysts more randomly arranged; from *Acicu-*

*lella* Pia, 1930 *non* 1927 emend. Elliott, 1971 by the dark-microgranular calcification.

**Occurrence.** – Late Viséan of Roc de Murviel in the Montagne Noire (MA-RM6, MA-RM9) and of southwest Spain in Peñarroya 2 (Pc-PÑR2/2, Pc-528), Peñarroya 3 (Pc-PÑR3/2c), Peñarroya 4 (Pc-PÑR4/2a, Pc-PÑR4/2b) (Cózar & Rodríguez 1999a), Sierra Palacios 1 (Pc-SPL1/2e, Pc-SPL1/5c) (Cózar & Rodríguez 1999b), El Collado (Pc-817, Pc-825) (Cózar 2004) and Fuenteovejuna (Pc-1798) (Cózar *et al.* 2007).

Kingdom and phylum indeterminate

Class Algospongia Termier *et al.*, 1977 *ex* Vachard & Cózar, 2010

Order Moravamminales Pokorny, 1951 *ex* Vachard *in* Termier *et al.*, 1975 nom. correct. herein; non Maslakova, 1990

Family Issinellaceae Deloffre, 1987 emend. Vachard & Cózar, 2010 nom. correct. herein

### Genus *Zidella* Saltovskaya, 1984

**Type species.** – *Zidella maxima* Saltovskaya, 1984.

**Synonyms.** – *Einoriella* (*sensu* Bogush *et al.* 1990, p. 107); *Issinella* (*sensu* Mamet & Martínez 1981 and Mamet 1991 part.).

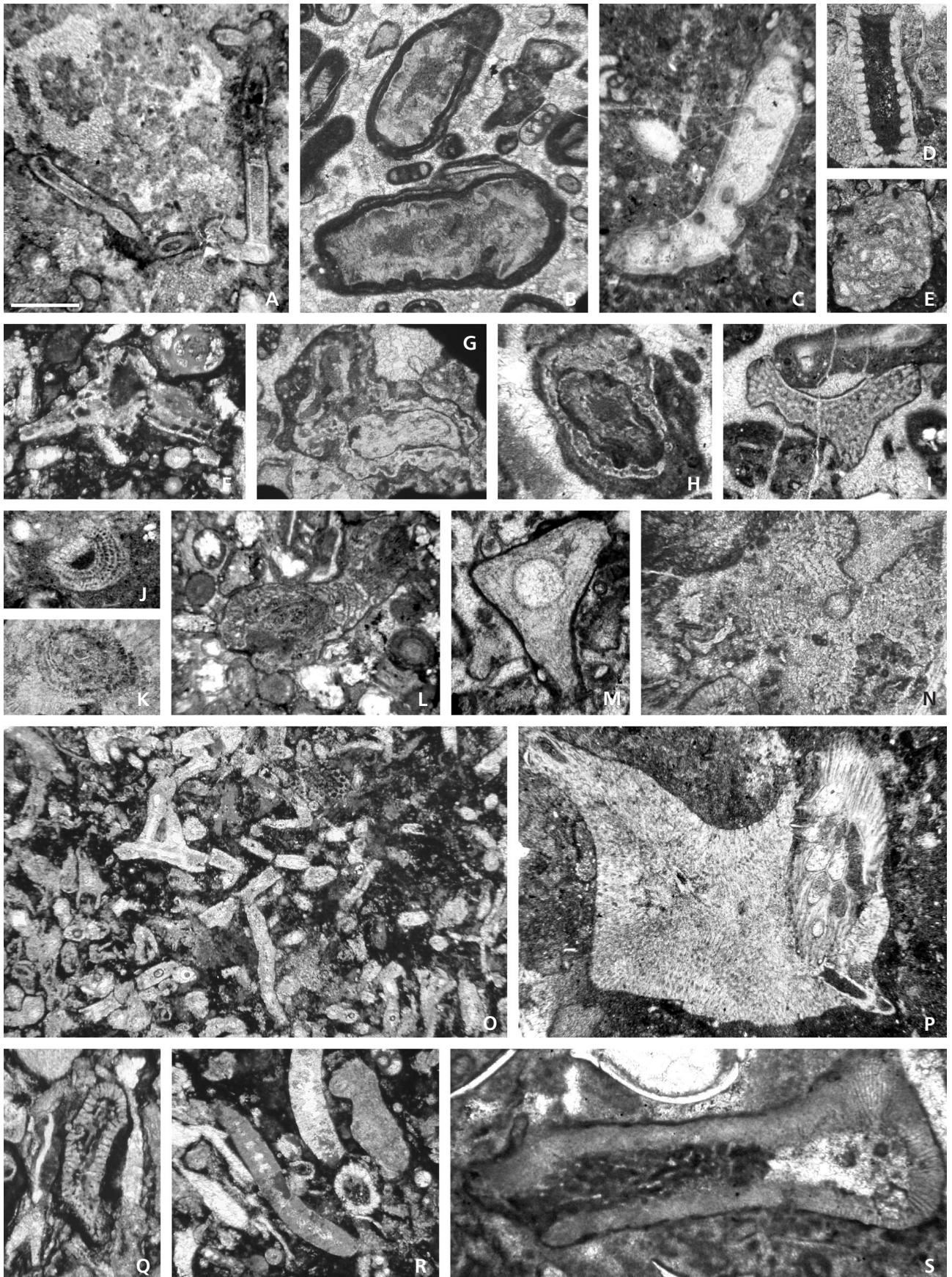
**Diagnosis.** – Cylindrical test, with external and internal surface irregularities and groups of blind, thin laterals linked in irregular rings within the skeleton. No diaphragms were observed (see Vachard 1991, fig. 2).

**Composition.** – *Zidella maxima* Saltovskaya, 1984; *Uraloporella aurivella* Vachard, 1977b.

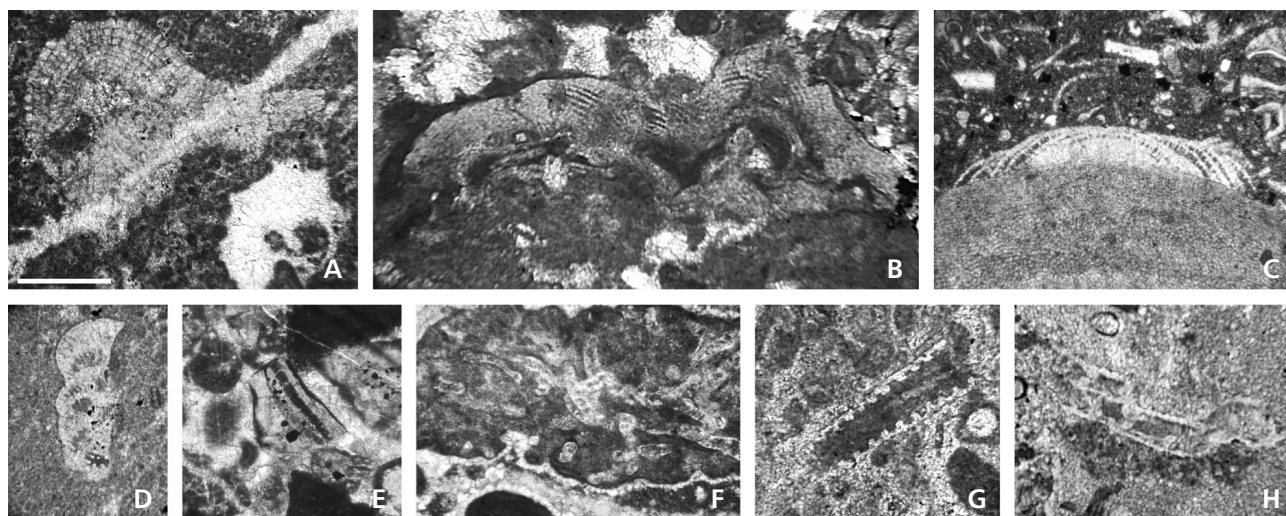
**Remarks.** – *Zidella* was questionably assigned to the family Uraloporelleae by Shuysky (1985, p. 94). Herbig & Mamet

**Figure 10.** Late Viséan–early Serpukhovian algospongia (scale bar = 0.5 mm). • A – *Issinella* sp., thin section MA-MN2, Les Mentaresses, latest Viséan. • B – *Zidella aurivella* (Vachard, 1977b), thin section DV-293f, Les lentilles de la route, late Viséan. • C – *Crassikamaena/Evlania* sp., thin section MA-RM34, Roc de Murviel, latest Viséan. • D – *Exvotarissella index* (Ehrenberg, 1854 *sensu* von Möller, 1879) Mamet & Roux, 1974, thin section DV-601A, Les Pascales, early Serpukhovian. • E – *Stacheoides polytrematoides* (Brady, 1876), thin section MA-10-9, Castelsec, early Serpukhovian. • F – *Costacheoides cannidahensis* (Mamet & Roux, 1983), thin section MA-10-12, Castelsec, early Serpukhovian. • G – *Asphaltinella horowitzi* Mamet & Roux, 1978, thin section DV-FB4, Les lentilles de la route, late Viséan. • H – *Claracrusta catenoides* (Homann, 1972) Vachard, 1980, thin section MA-10-1, Castelsec, early Serpukhovian. • I – *Sinustacheoides meandriformis* (Mamet & Rudloff, 1972) Termier *et al.*, 1977, thin section MA-RM3, Roc de Murviel, latest Viséan. • J – *Aoujgalia regularis* Termier *et al.*, 1977, thin section MA-RR7, Roque Redonde, latest Viséan. • K – *Aoujgalia richi* Mamet & Roux, 1978, thin section MA-RR4, Roque Redonde, latest Viséan. • L – *Valuzieria sescenti* Termier *et al.*, 1977 emend. herein, thin section MA-RM1, Roc de Murviel, latest Viséan. • M – *Aoujgalia variabilis* Termier & Termier, 1950, thin section MA-10-1, Castelsec, early Serpukhovian. • N – *Asteroaoujgalia gibshmanae* Brenckle, 2004, thin section Pc-4622, Les Pascales, early Serpukhovian. • O – *Kamaenella denbighi* Mamet & Roux, 1974, thin section DV-137f, Roc de Loup-Vailhan, late Viséan. • P – *Aoujgalia skimoensis* (Mamet & Rudloff, 1972), thin section Pc-4445, Roque Redonde, latest Viséan. • Q – *Roquesselsia cf. radians* Termier *et al.*, 1977, thin section MA-10-17, Castelsec, early Serpukhovian. • R – *Palaeoberesella lahusenii* (Möller, 1879) Mamet & Roux, 1974, thin section MA-10-12, Castelsec, early Serpukhovian. • S – *Roquesselsia radians* Termier *et al.*, 1977, thin section MA-10-7, Castelsec, early Serpukhovian.









**Figure 11.** Late Viséan–early Serpukhovian algaespongia (scale bar = 0.5 mm). • A – *Fourstonella irregularis* Mamet & Roux, 1977, thin section DV-248B, Roc de Loup-Vailhan, late Viséan. • B – *Fourstonella densifolia* (Vachard in Vachard & Montenat, 1981) ex Vachard & Cózar, 2010, thin section MA-10-14(2), Castelsec, early Serpukhovian. • C – *Fourstonella johnsoni* (Flügel, 1966) ex Vachard & Cózar, 2010, thin section Pc-4447, Roque Redonde, latest Viséan. • D – *Stacheia marginuloides* Brady, 1876, thin section MA-RM49, Roc de Murviel, latest Viséan. • E – *Fasciella scalaeformis* Vachard *et al.*, 2004, thin section DV-431, Mounio, late Viséan. • F – *Kamaenella?* sp., thin section DV-848, Les lentilles de la route, late Viséan. • G – *Kamaena?* sp., thin section DV-12-26, Roc du Cayla, latest Viséan. • H – kamaenacean transitional form to the beresellaceans, thin section MA-RM11, Roc de Murviel, early Serpukhovian.

(1994, text-fig. 4, p. 101) considered “*Luteotubus*, *Zidella*, etc.” (*sic*) as synonyms of *Issinella grandis* Chuvashov, 1965. However, this latter species, which is a true *Issinella* as recently redescribed by Okuyucu *et al.* (2013) (*i.e.*, a tube with any irregularities, and randomly arranged laterals), entirely differs from *Luteotubulus* (the exact spelling of this taxon) and *Zidella* (see remarks in Vachard 1993). Nevertheless, we admit that *Zidella minor* Ivanova, 1988 could be an *Issinella*.

**Occurrence.** – Late Viséan of Tien-Shan, Tajikistan (Saltovskaya 1984), central and southern Urals (*e.g.*, Ivanova 1988, Bogush *et al.* 1990, Ivanova & Bogush 1992), South China (Mamet & Préat 2013), Sumatra (Vachard 1989), central Morocco (Berkhli 1999, p. 108), Spain and Ireland (Vachard & Cózar 2010). Venevian (rather common) to Steshevian (rare) in the Montagne Noire (Pille 2008 re-interpreted and this study).

***Zidella aurivella* (Vachard, 1977b) emend. herein**  
Figure 10B

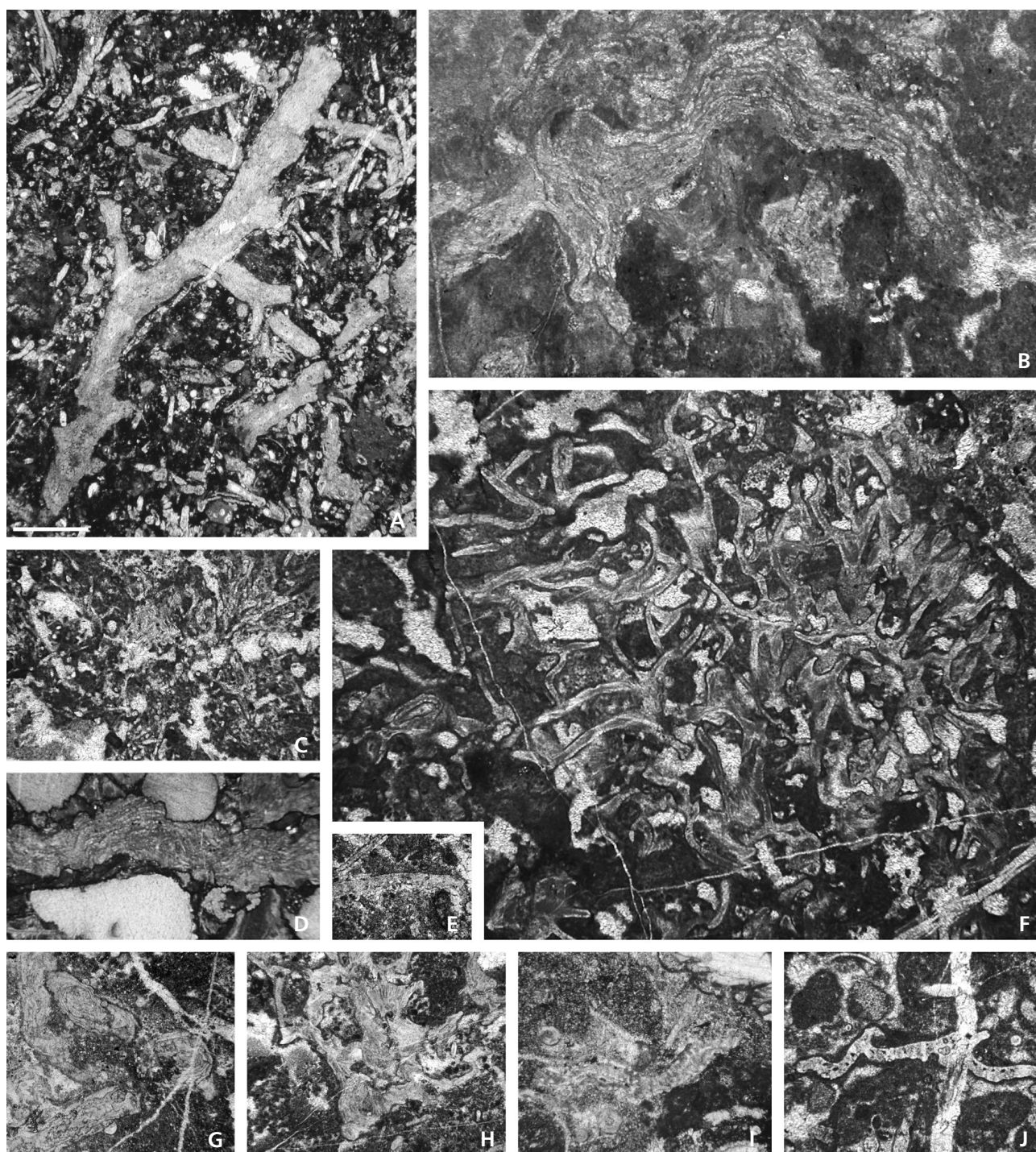
- v. 1974b *Uraloporella* cf. *sieswerdai* Rac. – Vachard, p. 182, pl. 8, figs 2, 3.
- v. 1977a *Uraloporella aurivella* Vachard. – Vachard, p. 374, table 1 (no illustration) (nomen nudum).
- v. 1977b *Uraloporella aurivella* Vachard, p. 133, pl. 1, fig. 11 (with one reference in synonymy).
- ?1981 *Issinella devonica* Reitlinger. – Mamet & Martínez, pl. 2, figs 2, 3 (or another species of *Zidella*).

- 1990 *Einoriella elongata* Saltovskaya. – Bogush *et al.*, p. 107, pl. 11, fig. 11.
- v. 1991 *Zidella aurivella* (Vachard). – Ouarache *et al.*, pp. 51–52 (no illustration).
- 1995 *Issinella lici* (Malakhova). – Sánchez-Chico *et al.*, pl. 1, fig. 7–5.
- v. 1998 *Zidella aurivella* (Vachard) n. comb. – Delvolvé *et al.*, p. 366 (no illustration).
- v. 2002 *Zidella aurivella* (Vachard). – Berkhli & Vachard, p. 69 (no illustration).
- 2008 *Zidella aurivella* (Vachard). – Pille, p. 65, pl. 21, figs 9–17.
- 2010 *Zidella aurivella* Vachard (*sic*: no parentheses). – Vachard & Cózar, p. 165, pl. 3, figs 4–6.
- ?2013 *Zidella?* *shangsiensis* Mamet & Préat, p. 41, pl. 6i.

**Description.** – This large species is especially well represented in the Lenses of the road, near Roquessels (Lentilles de la route), but rare specimens exist also in Roquemaière and Roc de Murviel. Length = 0.420–1.640 mm, outer diameter = 0.270–0.590 mm, inner diameter = 0.100–0.370 mm; wall thickness = 0.085–0.110 mm.

**Remarks.** – *Zidella aurivella* differs from *Z. maxima* in smaller dimensions, and from *Z. minor* Ivanova, 1988, in its larger parameters. *Zidella?* *shangsiensis* Mamet & Préat, 2013, which unquestionably belongs to *Zidella*, has the same profile and outer diameter (0.400–0.500 mm) as *Zidella aurivella*; however, this taxon is too poorly





**Figure 12.** Late Viséan–early Serpukhovian Calcifoliina (scale bar = 1 mm except for figures E, I and J = 0.5 mm). • A – *Ungdarella uralica* Maslov 1950, thin section DV-137f, Roc de Loup-Vailhan, late Viséan. • B – *Fasciella crustosa* Vachard et al., 2004, thin section MA-25-16, La Boutinelle, late Viséan. • C – *Praedonezella primitiva* Vachard et al., 2004, thin section MA-LS Feldweg 17, La Serre-vineyard, early Serpukhovian. • D – *Fascifolium pantherium* Vachard & Cózar, 2010, thin section MA-SP18, La Serre de Péret, early Serpukhovian. • E – *Calcifolium okense* Shvetsov & Birina, 1935, thin section Pc-4590, Roc du Cayla, latest Viséan. • F – *Falsocalcifolium punctatum* (Maslov, 1956), thin section MA-LS Feldweg 58, La Serre-vineyard, early Serpukhovian. • G – *Fasciella kizilia* Ivanova, 1973, thin section DV-620, Japhet, late Viséan. • H – *Falsocalcifolium punctatum* (Maslov, 1956), thin section Pc-4540, Castelsec, early Serpukhovian. • I – *Falsocalcifolium punctatum* (Maslov, 1956), thin section DV-687a, Les Mentaresses, latest Viséan. • J – *Calcifolium okense* Shvetsov & Birina, 1935, thin section Pc-4593, Roc du Cayla, latest Viséan.



illustrated to definitively conclude that it is a junior synonym of this latter species.

The taxon *Einoriella elongata sensu* Bogush *et al.* (1990, p. 107, pl. 11, fig. 11; *non* Saltovskaya, 1984) possesses the same dimensions as *Zidella aurivella*. Nevertheless, as the true *E. elongata* more resemble species of *Donezella*, we assign herein the misinterpreted taxon of Bogush *et al.* (1990) to *Zidella aurivella*.

**Occurrence.** – Late Viséan of Tien-Shan, central and southern Urals, South China and Sumatra. Late or latest Asbian? of central Morocco and South China (Shangsi Fm). Questionable in Spain. Venevian (relatively common) to Tarusian–Steshevian (rare) in the Montagne Noire: Lenses of the road (DV293D, DV293E including the holotype, DV293F, DV293G, DV293H, DV293.2.C, DV332'A, DVFB4; see Vachard & Cózar 2010, pl. 3, figs 4, 6); sommet 224-Valuzières (DV600B, see Vachard & Cózar 2010, pl. 3, fig. 5); Roquemaillère (DV134F, DV134G); and Roc de Murviel (MA82, MA83).

Order Aoujgaliales Termier *et al.*, 1975 *ex* Vachard & Cózar, 2010 nom. correct. herein  
Suborder Aoujgaliina Termier *et al.*, 1975 nom. transl. Vachard & Cózar, 2010  
Family Aoujgaliaceae Termier *et al.*, 1975 nom. correct. Brenckle, 1977  
Tribe Aoujgaliae Termier *et al.*, 1975 nomen transl. Chuvashov *in* Chuvashov *et al.*, 1987

### Genus *Valuzieria* Termier *et al.*, 1977 emend. herein

*Type species.* – *Valuzieria sescenti* Termier *et al.*, 1977.

*Diagnosis.* – Similar to *Aoujgalia* Termier & Termier, 1950, but with turriform expansions, and an alignment of the lateral walls of the cells.

*Remarks.* – Created as a distinct genus by Termier *et al.* (1977), *Valuzieria* was synonymized with *Aoujgalia* by Vachard & Cózar (2010). However, our new material proved that *Valuzieria* is transitional between *Aoujgalia* and *Asteroaoujgalia*, and not really synonymous of one or each other of both genera. Consequently, we re-describe here *Valuzieria* as a valid genus and we indicate its differences with the two genera. Even if rare arms are common among the aoujgaliaceans (see *e.g.*, Krings *et al.* 1987, pl. 5, fig. 3; Brenckle & Marchant 1987, pl. 5, fig. 3; Vachard & Cózar 2010, pl. 9, figs 13, 18), they are first really developed in *Valuzieria*, which announces the numerous arms of *Asteroaoujgalia*.

*Occurrence.* – Early–late Brigantian of the Montagne Noire and central Morocco.

### *Valuzieria sescenti* Termier *et al.*, 1977

Figure 10L

- p. 1974 *Stacheoides*. – Rich, pl. 4, fig. 21 (*non* pp. 371–372, *nec* pl. 4, figs 1–5 = true *Stacheoides*).
- v. 1977 *Valuzieria sescenti* Termier *et al.*, pp. 154–155, pl. 6, fig. 1.
- v. 1977a *Valuzieria sescenti* Termier & Vachard (*sic.*) – Vachard, p. 374, table 1 (no illustration).
- ? 1983 *Stacheoides* sp. – Vieslet, pl. 5, fig. 4.
- ? v. 1991 *Valuzieria* sp. – Ouarache *et al.*, pp. 50, 52 (no illustration).
- v. non 1991 *Valuzieria sescenti* Termier, Termier & Vachard. – Vachard *et al.*, pl. 1, fig. 7 (most probably *Stacheoides*).
- v. 1999 *Valuzieria* sp. – Berkli, p. 111 (no illustration).
- v. 2008 *Valuzieria sescenti* G. Termier *et al.* – Pille, p. 84, pl. 27, figs 1–5.
- v. 2010 *Aoujgalia* (= *Valuzieria*) *sescenti* G. Termier *et al.* – Vachard & Cózar, p. 194, pl. 9, figs 1–5.

*Description.* – The holotype was defined in the sample DV600B of sommet 224-Valuzières. Maximal dimension of thallus = 2.000 mm, thickness of skeletal elements = 0.020–0.050 mm, dimensions of cells = 0.050–0.070 mm.

*Occurrence.* – This form remains very rare in the type locality, sommet 224-Valuzières, in DV600A (two specimens) and DV600B (two specimens). Four other specimens were discovered in Roc de Murviel (MA-83) and Les Jeantels (DV690C) by Pille (2008). A new specimen from Roc de Murviel (MA-RM1) is illustrated herein. Representative specimens of the transition to *Asteroaoujgalia* have been discovered in central Morocco (Tizra 2 and Mouarhaz sections) by Vachard & Cózar (2010); they are presumably present in the Montagne Noire.

### Genus *Asteroaoujgalia* Brenckle, 2004 emend. herein

*Type species.* – *Asteroaoujgalia gibshmanae* Brenckle, 2004.

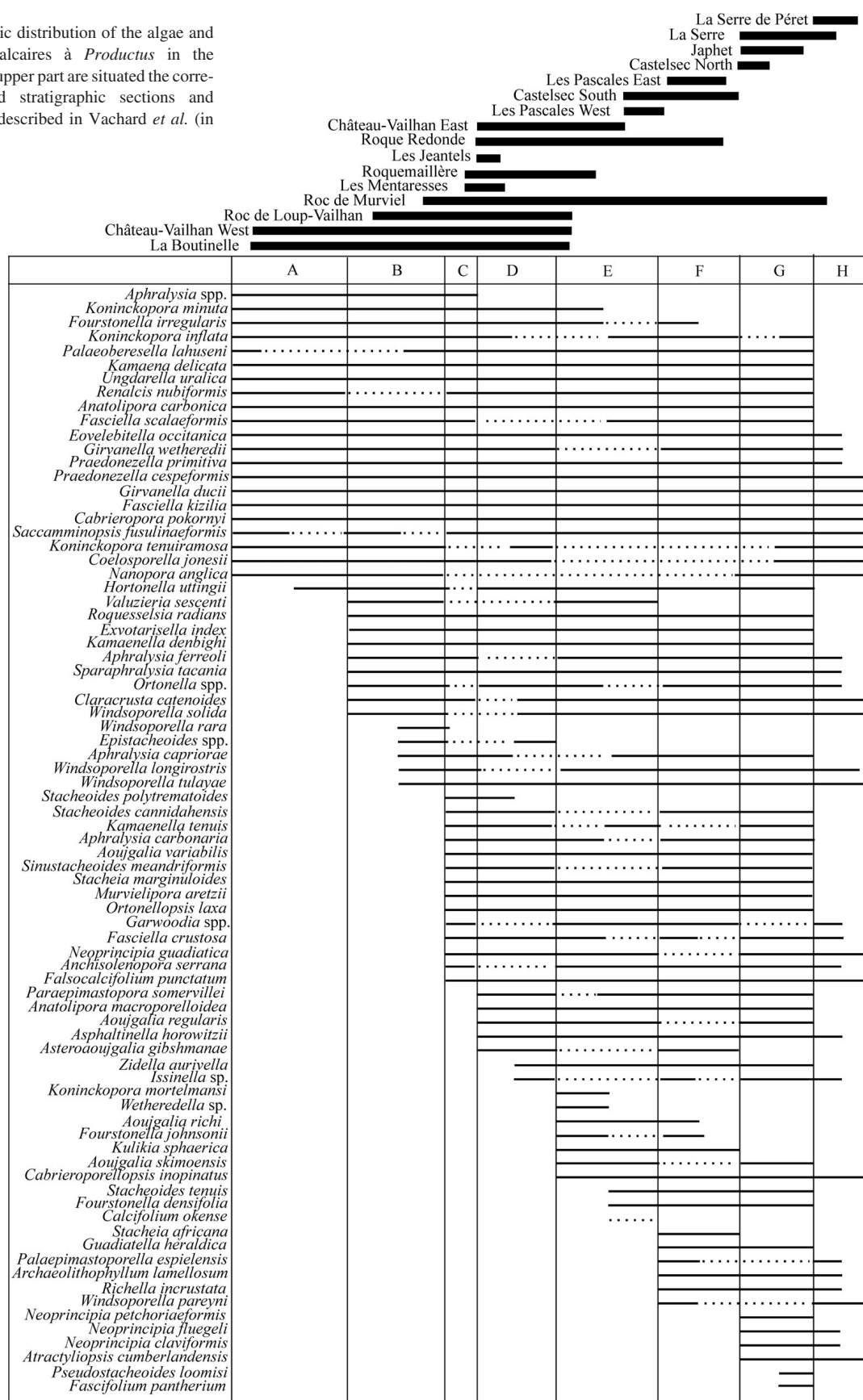
*Emended diagnosis.* – Aoujgaliidae with concentric rows of quadratic chamberlets and numerous turriform expansions.

*Composition.* – Monospecific.

*Remarks.* – *Asteroaoujgalia*, although assigned with doubt to the Aoujgaliaceae by Brenckle (2004), unquestionably belongs to this family. It is relatively similar to *Aoujgalia* and *Valuzieria* but differs from these two genera by its more numerous turriform expansions and its pillars less



**Figure 13.** Stratigraphic distribution of the algae and algaespongia in the Calcaires à *Productus* in the Montagne Noire. In the upper part are situated the correlations of the studied stratigraphic sections and foraminiferal biozones described in Vachard *et al.* (in press).



regularly and vertically aligned; nevertheless, intermediate cases exist, see *e.g.*, the specimens illustrated by Brenckle 2004, pl. 8, fig. 5 (left, bottom).

**Occurrence.** – Late Viséan of Tarim (China) and Serpukhovian of Precaspian Basin (Kazakhstan) (Brenckle 2004). Late Brigantian of Boulonnais, northern France (D.V. unpublished data). Discovered in the early Serpukhovian of the Montagne Noire.

#### ***Asteroaoujgalia gibshmanae* Brenckle, 2004**

Figure 10N

2004 *Asteroaoujgalia gibshmanae* Brenckle, pp. 159, 161, pl. 7, fig. 1, pl. 8, figs 1–7.

2010 *Asteroaoujgalia gibshmanae* Brenckle. – Vachard & Cózar, p. 192 (no illustration).

**Description.** – Maximal dimension of thallus = 2.160 mm × 1.530 mm, thickness of skeletal elements = 0.030–0.060 mm, dimensions of cells = 0.075–0.080 mm.

**Occurrence.** – As for the genus.

## **Discussion**

It has long been recognized that several cyanobacteria, algae and algaesponges are limited to the Mississippian and/or Pennsylvanian (*e.g.*, Garwood 1914; Wood 1940, 1942, 1963, 1964; Johnson & Konishi 1956; Maslov 1956; Elliott 1968a; Petryk & Mamet 1972; Emberger 1976; Vachard & Cózar 2010) and the importance of some algae and algaesponges at least as regional biostratigraphic markers has been clearly demonstrated (*e.g.*, Mamet & Rudloff 1972; Vachard 1977a, b; Perret & Vachard 1977; Skompski 1981, 1986, 1987; Mamet & Roux 1983; Skompski *et al.* 1989; Mamet 1991, 1997, 2002, 2006; Vachard & Berkhli 1992; Sebbar & Mamet 1996, 1999; Mamet *et al.* 1996; Sebbar 1998; Berkhli & Vachard 2001; Krainer & Vachard 2002; Cózar 2004, 2005; Cózar & Somerville 2004, 2005a–c; Cózar *et al.* 2008, 2009; Pille 2008; Somerville 2008; Pille & Vachard 2011). Several genera first appear and diversify in the late Viséan and Serpukhovian; *e.g.*, *Ungdarella*, *Kulikia*, *Neoprincipia*, *Richella*, *Archaeolithophyllum*, *Falsocalcifolium* and *Calcifolium* (see Burgess 1965, Termier *et al.* 1975, Conil *et al.* 1980, Mamet *et al.* 1980, Cózar & Vachard 2003, Vachard & Cózar 2005, Cózar & Somerville 2005a, b, Pille 2008, Somerville 2008).

The detailed stratigraphic distribution (Fig. 13) of the algal taxa identified in various outcrops of the “calcaires à *Productus*”, not only enable to confirm the regional

biozones based on foraminiferal assemblages (Vachard *et al.*, in press), but also helps to identify finer stratigraphic intervals.

(a) *Fourstonella irregularis* Mamet & Roux, 1977, *Anatolipora carbonica*, *Fasciella scalaeformis* Vachard *et al.*, 2004, *Eovelebitella occitanica* Vachard, 1974a, *Cabrieropora pokornyi* Mamet & Roux, 1975a, *Saccaminopsis fusulinaeformis* (McCoy, 1849), *Coelosporella jonesii* Wood, 1940, *Praedonezella primitiva* Vachard *et al.*, 2004, and *P. cespeformis* (Kulik, 1973) are recorded from the late Viséan biozone A.

(b) The different species of *Aphralysia* are common in the late–latest Viséan biozones A, B and C.

(c) *Koninckopora* spp., present in late–latest Viséan biozones A to D, are rare in latest Viséan–Serpukhovian biozones E to H. *Koninckopora mortelmansi* is regionally limited to the latest Viséan biozones D–E and early Serpukhovian F–H.

(d) *Valuzeria sescenti* is restricted to the late–latest Viséan biozones B–E.

(e) *Sparaphralysia* is known from the late Viséan to Serpukhovian biozones B to H.

(f) The FO of *Claracrusta* is located at the base of the late Viséan biozone B. That is probably also the FAD of this taxon based on the data of the literature.

(g) The late Viséan biozone B is characterized by the presence of different species of *Windsoporella*. *W. rara* is limited to the uppermost Mikhailovian (upper B).

(h) The latest Viséan biozone C is characterized by the FOs of *Murvielipora*, *Ortonellopsis*, *Fasciella crustosa* Vachard *et al.*, 2004, *Neoprincipia guadiatica* Cózar & Vachard, 2003, *Anchisolenopora serrana*, and *Falsocalcifolium punctatum* (Maslov, 1956).

(i) In latest Viséan biozone D, the FOs of *Anatolipora macroporelloidea* sp. nov., *Paraepimastopora somervillei* sp. nov., *Zidella aurivella*, and *Asteroaoujgalia gibshmanae* are recorded.

(j) The latest Viséan biozone E is principally characterized by the FOs of *Kulikia sphaerica*, *Cabrieroporellopsis inopinatus*, and various atypical *Fourstonella* spp. (*F. johnsoni* and *F. chuvashovia*).

(k) The early Serpukhovian biozone F is principally characterized by the FOs of *Archaeolithophyllum lamellosum* Wray, 1964 and *Richella incrustata*.

(l) The early Serpukhovian biozone G is characterized by the FOs of three small species of *Neoprincipia*: *N. petschoriaformis*, *N. fluegeli*, and *N. claviformis*.

(m) Currently, no algal markers characterize the late Serpukhovian biozone H.

Compared to other European areas, the cyanobacteria *Aphralysia* might be of higher biostratigraphic value in the Viséan–Serpukhovian boundary interval of the Montagne Noire, due its abundance and the numerous cited species. However, thorough taxonomical and biostratigraphical



studies of this genus are needed in other regions in order to evaluate its biostratigraphical potential for interregional correlation.

The distribution of *Saccamminopsis* in England is late-latest Viséan, Aleksinian-Venevian (Hawes-Three Yard; Hallett 1971), whereas it is late Viséan to early Serpukhovian, Mikhailovian–Steshevian in the Montagne Noire.

*Koninckopora* is a well-known problematic dasyclad with a cosmopolitan distribution, which was long time considered as restricted to the middle-late Viséan around the world (e.g., Termier et al. 1975, Vachard & Berkhli 1992, Berkhli & Vachard 2001, Pille 2008). However, in recent years, several discoveries in the Serpukhovian have been mentioned *Koninckopora* in China (Mamet 1991, Groves et al. 2012), SW Spain (Cózar 2005) and the Moroccan Meseta (Cózar et al. 2008). In the Montagne Noire, different species of *Koninckopora* also exist in the early Serpukhovian (biozones F–H). Furthermore, a unquestionable late Serpukhovian occurrence of *Koninckopora* has been documented in the Tindouf Basin (Cózar et al. 2014).

*Coelosporella* was known to appear in the late Viséan in England, southern France and eastern Morocco (Hallett 1971, Vachard 1977b, Vachard & Berkhli 1992, Pille 2008). It has been documented up to the late Serpukhovian in SW Spain (Cózar 2005), and it is present in the Bashkirian of the western Moroccan Meseta (Cózar et al. 2011). In the Montagne Noire, the genus is present in all late Viséan to Serpukhovian biozones A to H (i.e., from Mikhailovian to Steshevian).

Another long-ranged taxon in the Montagne Noire is *Nanopora*. However, this long-range is not surprising because this genus also subsists up to the late Serpukhovian in the Pyrénées (Perret & Vachard 1977, Pille 2008), SW Spain (Cózar 2005) and Western Moroccan Meseta (Cózar et al. 2011), and even reaches into the Bashkirian in the Tindouf Basin (Cózar et al. 2014).

Possible polyphysacean dasycladales, with *Neoradiosphaeroporella* gen. nov., appear in the biozones G–H of the late? early Serpukhovian in the Montagne Noire; “*Atractyliopsis*” (but probably to re-name) appears in the early Serpukhovian in the Tindouf Basin (Cózar et al. 2014) and the Béchar Basin (Sebbar & Mamet 1996), and in the late Serpukhovian of the Western Moroccan Meseta (Cózar et al. 2011). In Tindouf, a new species of the same false-“*Atractyliopsis*” is then characteristic of the latest Serpukhovian to Bashkirian interval. In the Montagne Noire, possible polyphysaceans *Neoradiosphaeroporella* gen. nov. appear almost coevally; i.e., in the biozone G of the late early Serpukhovian.

*Zidella* is a Mikhailovian genus of Tajikistan, South China and Sumatra (Vachard & Cózar 2010), also known in the Serpukhovian of Tindouf (Cózar et al. 2014). In the Montagne Noire, *Zidella* is present from B to G; therefore,

it appears to be characteristic for the Viséan–Serpukhovian boundary interval identified in this study.

*Calcifolium okense* is rare in lower Venevian (Five Yard), common in the upper Venevian (Three Yard)-Tarusian (Underset) in northern England (Hallett 1971). In the Montagne Noire, this species is extremely rare and localized in rocks assigned to the early Serpukhovian biozone F.

## Conclusions

1. The “calcaires à *Productus*” of the southern Montagne Noire contains rich cyanobacterial and algal microfloras which are taxonomically and biostratigraphically revised herein.

2. The cyanobacteria are generically well known. The particularities of the assemblages are the diversity of the genera *Renalcis* and *Aphralysia*. A new genus *Ortonellopsis* gen. nov. displays a very loose organisation of its network of trichomes.

The rare red algae also were relatively well known, especially the species of *Neoprincipia* and *Archaeolithophyllum*. A new genus is described, *Anchisolenopora* gen. nov., which might justify a transition at least morphological between cyanobacteria and red algae.

Among the green algae, the true dasycladales recently redescribed, and the regionally rare *Koninckopora*, are not rediscussed herein; except for *Paraepimastopora somervillei* sp. nov. in order to indicate an accurate dating of the appearance of the epimastoporacean lineages. The regionally abundant group of uncommon metaspondyl dasycladales, Borlatelleae trib. nov., is analyzed as well as *Neoradiosphaeroporella aprica* gen. et sp. nov., which is possibly the first real representative of the very specialized group of the polyphysacean dasycladales.

3. The group of the Anatoliporaceae is revised, also due to its regional importance, and hypothetically assigned to the ulotrichales. The new taxon *Anatolipora macroporelloidea* sp. nov. is described.

4. About the *incertae sedis* aujgaliales, only new informations are provided on *Zidella*, often common in the “calcaires à *Productus*”, as well as on rare *Valuzieria* and *Asteroaujgalia*. Phylogenetically, these two latter genera appear very closely related.

5. The detailed stratigraphic distribution of the cyanobacterial and algal taxa enables to refine and better characterize the recently defined regional biozones A to H based on foraminiferal assemblages. The distribution of algae help to identify finer stratigraphic intervals.

(a) The late Viséan biozone A (early Mikhailovian) is characterized by *Fourstonella irregularis*, *Anatolipora carbonica*, *Fasciella scalaeformis*, *Eovelebitella occitanica*, *Cabrieropora pokornyi*, *Saccamminopsis fusulinaeformis*, *Coelosporella jonesii*, *Praedonezella primitiva*, and *P. cespeformis*.

(b) The late Viséan biozone B (late Mikhailovian) is typified by different species of *Windsoporella*; among them, *W. solida* is limited to the latest Mikhailovian (upper B).

(c) The latest Viséan biozone C (early Venevian) is identified by the FOs of *Murvielipora*, *Ortonellopsis* gen. nov., *Fasciella crustosa*, *Neoprincipia guadiatica*, *Anchisolenopora serrana*, and *Falsocalcifolium punctatum*.

(d) In latest Viséan biozone D, the FOs of *Asteroaoujgalia gibshmanae*, *Zidella aurivella*, and *Anatolipora macroporelloidea* are recorded.

(e) The late Viséan biozone E is principally marked by the FOs of *Kulikia sphaerica*, *Cabrieroporellopsis inopinatus*, and various atypical *Fourstonella* spp. (like *F. johnsoni* and *F. chuvashovia*).

(f) The early Serpukhovian biozone F is based on the FOs of *Archaeolithophyllum lamellosum* and *Richella incrustata*.

(g) The early Serpukhovian biozone G is characterized by three small species of *Neoprincipia*: *N. petschoriaformis*, *N. fluegeli*, and *N. claviformis* and by the possible first polyphysaceans *Neosphaeroporella aprica* gen. et sp. nov.

(h) Currently, no algal markers have been found in the foraminiferal late Serpukhovian biozone H.

6. The algal microflora of the Montagne Noire contains numerous biostratigraphical markers in the Viséan–Serpukhovian boundary interval, and might help to foster the stratigraphic framework of this interval.

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