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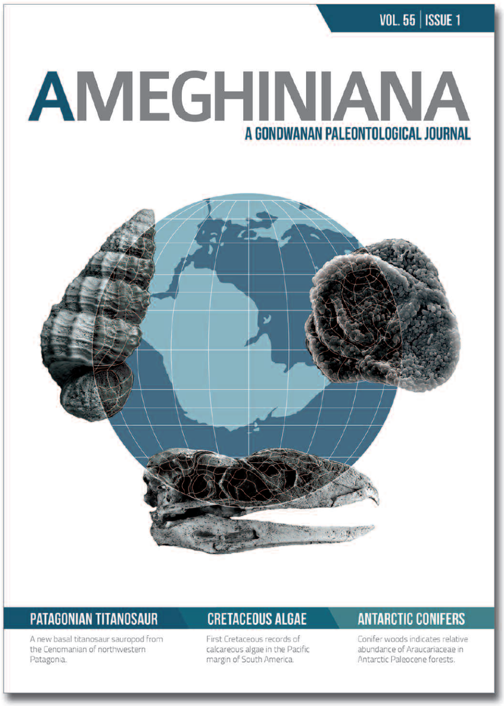
VOL. 55 | ISSUE 1

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PATAGONIAN TITANOSAUR
A new basal titanosaur sauropod from the Cenomanian of northwestern Patagonia.

CRETACEOUS ALGAE
First Cretaceous records of calcareous algae in the Pacific margin of South America.

ANTARCTIC CONIFERS
Conifer woods indicates relative abundance of Araucariaceae in Antarctic Paleocene forests.

FIRST RECORD OF CRETACEOUS CALCAREOUS ALGAE ON THE PACIFIC MARGIN OF SOUTH AMERICA (PERU)

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Submitted: February 6th, 2017 - **Accepted:** July 17th, 2017 - **Published online:** July 22nd, 2017

To cite this article: Bruno Granier, and Étienne Jaillard (2018). First record of cretaceous calcareous algae on the Pacific margin of South America (Peru). *Ameghiniana* 55: 75–90.

To link to this article: http://dx.doi.org/10.5710/AMGH.17.07.2017.3093

ISSN 0002-7014

AMEGHINIANA - 2018 - Volume 55 (1): 75 – 90

ARTICLES

FIRST RECORD OF CRETACEOUS CALCAREOUS ALGAE ON THE PACIFIC MARGIN OF SOUTH AMERICA (PERU)

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Abstract. Study of carbonate facies from Cretaceous lithostratigraphic units of Peru has led to the identification of calcareous algae, mainly Dasycladales (*Apinella hispanica*, *Salpingoporella* ? *hasi*, *Korkyrella* sp., *Neomeris* spp., *Trinocladus divnae*, and *Terquemella* spp.), mostly from Cenomanian strata. These algae represent the first records of these taxa on the Pacific margin of South America, in a back-arc setting.

Key words. Calcareous algae. Cretaceous. Peru.

Resumen. PRIMER REGISTRO DE ALGAS CALCÁREAS CRETÁCICAS EN EL MARGEN PACÍFICO DE AMÉRICA DEL SUR (PERÚ). El estudio de las facies de unidades litoestratigráficas cretácicas del Perú llevó a identificar algas calcáreas, mayoritariamente Dasycladales (*Apinella hispanica*, *Salpingoporella* ? *hasi*, *Korkyrella* sp., *Neomeris* spp., *Trinocladus divnae* y *Terquemella* spp.), principalmente de estratos cenomanianos. Dichas algas representan el primer registro de algas calcáreas en el margen pacífico de América del Sur, en un contexto de trasarco.

Palabras clave. Algas calcáreas. Cretácico. Perú.

THERE are relatively few records of Cretaceous calcareous algae from South and Central America (see reviews by Granier *et al.*, 1991a, 2008; Granier, 2015). Most records come from Brazil (Howe *in* Maury, 1937; Tibana and Terra, 1981; Srivastava, 1982a, 1982b, 1984; Berthou and Bengtson, 1988; Terra, 1990; Granier *et al.*, 1991a, 1991b, 2008, 2012a, 2012b, 2014; Terra and Lemos, 1999; Woelkerling *et al.*, 2014; Granier and Dias-Brito, 2016a, 2016b) and Venezuela (Masse and Rossi, 1987) on the Atlantic margin of the South American plate, and also from Guatemala (Johnson and Konishi, 1960; Johnson and Kaska, 1965; Granier *et al.*, 2013; Granier and Dias-Brito, 2016a, 2016b; Granier *et al.*, 2017) and Chiapas, Mexico (Deloffre *et al.*, 1985; Michaud, 1988), on the southern margin of the North American plate. Except for the "Dasycladales" illustrated by Leguizamon *et al.* (1993) that are not algae but bryozoans (Granier *et al.*, 2008), there are no further records from these regions.

The purpose of this paper is to describe for the first time fossil calcareous algae from three Cretaceous outcrops of south (Arequipa and Moquegua regions) and central (Lima Region) Peru. The assemblages are largely dominated by Dasycladales, *i.e.*, calcareous green algae, the occurrences of which question or confirm previous age assignments. Although they represent the first records on the Pacific margin of South America, in a back-arc setting, insufficient data are available regarding this ocean (Masse and Arnaud-Vanneau, 1999) to enable meaningful paleobiogeographic discussion.

STRATIGRAPHIC SETTING AND AGE

During the Cretaceous, the Peruvian active margin was subjected to the subduction of the oceanic paleo-Pacific plate. It comprises a fore-arc zone (presently offshore), an arc zone (present-day coastal zone) and a shallow, back-arc basin (most of the Andean chain). All studied outcrops are located in the back-arc zone.

Central Peru (Lima Region)

The Oyón section begins at 10° 39′ 10.8″ S; 76° 42′ 19.0″ W (Fig. 1). The fossiliferous strata are part of the Jumasha Formation, which was assigned a late Albian–early Turonian age (Wilson, 1963; Jaillard, 1986). Thin sections labelled JU-45 and JU-51, supposedly late Albian in age, include *Neomeris* sp. (Fig. 4.10) and unindentified *Halimeda* sp. A thin section labelled JU-63 includes *Trinocladus divnae* Radoičić, 2006, which was originally described from Cenomanian strata in Serbia, unidentified *Halimeda* sp., and the foraminifer *Archaias* (*Perouvianella*) *peruviana* (Steinmann, 1929) [identification by J.-J. Fleury]. The latter was first considered characteristic of the Santonian in Peru (Bizon *et al.*, 1976), but was later proved to be Cenomanian in age (Jaillard and Arnaud-Vanneau, 1993).

South Peru (Arequipa and Moquegua regions)

The Arcurquina section (Arequipa Region) begins at 16° 08′ 45.0″ S; 71° 49′ 51.0″ W (Fig. 1). The fossiliferous strata are part of the Arcurquina Formation (Benavides, 1962), which was assigned a Cenomanian age (Jaillard, 1995). A thin section labelled AC-66 includes *Salpingoporella* ? *hasi* Conrad *et al.*, 1976 (originally described from Cenomanian strata in Kosovo), *Neomeris* sp., and *Terquemella* sp.

The Carumas section (Moquegua Region) begins at 16° 48′ 01.0″ S; 70° 42′ 27.0″ W (Fig. 1). The fossiliferous strata belong to the Huancané and Omoye stratigraphic units. The sandy Huancané Formation, Goyllarisquizga Group, was dated as Early Cretaceous by García (1978). Its lower, fine-grained part includes interbedded limestones that could be correlative with the Valanginian marine transgression recorded locally in northern Peru (Benavides, 1956). From these samples, notably in thin sections labelled OY-101a, we identified numerous rhodolithes consisting of *Marinella lugeoni* Pfender, 1939 (commonly microbored), and some *Terquemella* sp. The Omoye Formation, which overlies terrestrial andesites, dacites and agglomerates of the imprecisely dated (Albian–Cenomanian) Matalaque Formation, was originally dated as Senonian (García, 1978; Jaillard, 1994). Thin sections, labelled OY-136c and OY-137f, include *Apinella hispanica* (Conrad and Grábner, 1975) and *Korkyrella* sp., both suggesting an older age, at least Cenomanian. The underlying Matalaque Formation would be, therefore, mainly Albian in age.

MATERIALS AND METHODS

The material studied consists of 12 thin sections from Carumas (OY) and 4 from Arcurquina (AC), both localities in South Peru, as well as 10 thin sections from Oyón (JU), Central Peru. This Peruvian material, bearing the label “Leg. É. Jaillard”, is registered with **LPB** (Laboratoire de Paléontologie de Brest) numbers in the collections of the Département des Sciences de la Terre et de l’Univers, Université de Bretagne Occidentale, Brest (France).

Abbreviations. L, length of the specimen; **D,** its outer diameter; **d,** its inner diameter/diameter of the main axis or of the axial cavity; **h,** height of the verticils; **p,** width of the primary pores; **l,** length of the primary pores; **w,** number of pores per verticil; **min,** minimum/proximal; **max,** maximum/distal.

SYSTEMATIC PALEONTOLOGY

Phylum Chlorophyta (Reichenbach, 1828)
Class Dasycladophyceae Hoek *et al.*, 1995
Order Dasycladales Pascher, 1931
Family Triploporellaceae (Pia, 1920)
Tribe Salpingoporelleae Bassoullet *et al.*, 1979

Remarks. Tribe Salpingoporelleae comprises those Dasycladales with cylindrical to slightly claviform thalli bearing verticils of laterals with no secondary extensions. The pores that are present within the calcareous coating of the algae and correspond to these primaries are either open [*e.g.*, *Apinella jaffrezoi* Granier *et al.*, 1986, and *Salpingoporella* (Pia *in* Trauth, 1917)] or closed (*e.g.*, *Holosporella* Pia, 1930) at their distal end. Due to their simple body plan these algae have few features and related parameters that enable taxonomic identification, at either generic or specific level. This simplicity is the source of controversies as, for instance, the ongoing debate about the uniqueness of the genus *Apinella* Granier *et al.*, 1986, documented below.

Genus ***Apinella*** Granier *et al.*, 1986

Type species. *Apinella jaffrezoi* Granier *et al.*, 1986; original designation. Kimmeridgian of Mexico.

Discussion. Some researchers (Sokač, 1996; Carras *et al.*, 2006) considered that *Apinella jaffrezoi* Granier *et al.*, 1986, from the Kimmeridgian of Mexico, is a junior synonym of “*Salpingoporella hispanica* Conrad *in* Conrad and Grábner, 1975” from the Barremian of Spain. Partly on this basis,

Figure 1. Location map of the fossil localities (dots).

they rejected the putative distinctiveness of the genus *Apinella* Granier *et al.*, 1986, and treated it as a junior synonym of *Salpingoporella* (Pia *in* Trauth, 1917). However, that is not accepted by all palaeophycologists (Granier *et al.*, 1986; Granier and Deloffre, 1993; Bucur, 1994; Bucur *et al.*, 2000), for the following reasons.

At the species level, for instance, the biometric parameters of *Apinella jaffrezoi* (Fig. 2.1–12, 18–19) significantly differ from those of *Apinella hispanica* (Fig. 2.16–17) and those of *Apinella urladanasi* (Conrad *et al.*, 1977) (Fig. 2.13–15). In addition, there is no record to date of either *A. jaffrezoi* or *A. hispanica* in the Tithonian–Valanginian interval spanning some 20 Ma.

At generic level, the primaries of *Apinella* are not of the typical phloiophorous type as documented in *Salpingoporella* or in *Macroporella* (Pia, 1912) (see Granier and Sander, 2013). Although the corresponding pores are open at their distal ends, the primaries of *Apinella* are closer to the vesicular type, *i.e.*, each having a short peduncle that precedes the rapid proximal widening of the lateral. In addition, compared to the thallus diameter, *Apinella*'s main axis (Fig. 3) is usually relatively wider than *Salpingoporella*'s main axis (Fig. 5).

On the basis of this analysis and contrary to the views of Sokač (1996) and others (*e.g.*, Carras *et al.*, 2006), we recognize here two discrete species (namely *Apinella hispanica* and *A. jaffrezoi*) ascribed to a single genus, rather than a single species ascribed to the genus *Salpingoporella*.

Apinella hispanica (Conrad *in* Conrad and Grábner, 1975)
Figures 2.1–12, 18–19

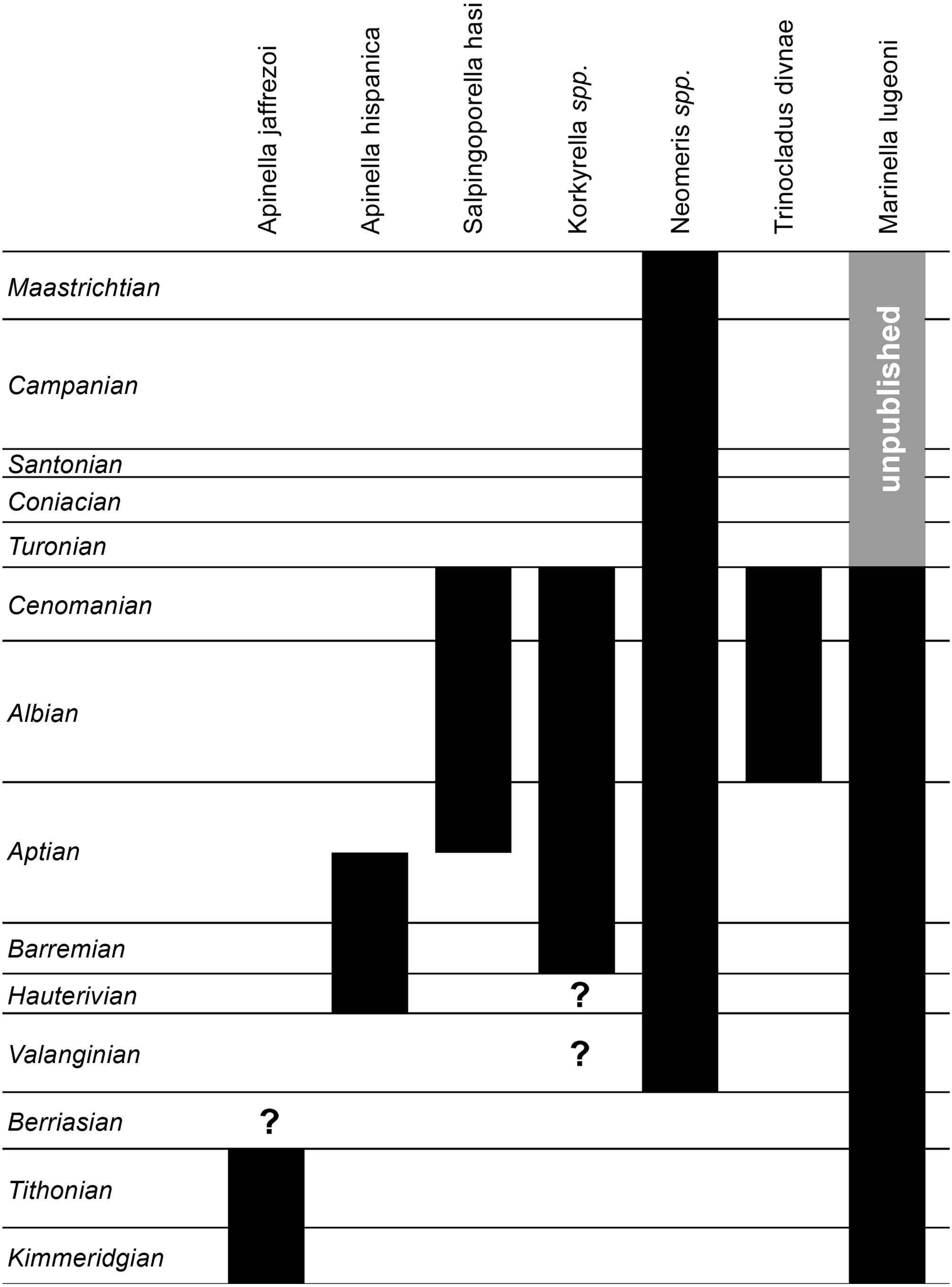
1975\. *Salpingoporella hispanica* n. sp., Conrad *in* Conrad and Grábner, p. 33–38, text-figs. 2–7.
1978\. *Salpingoporella hispanica*, Bassoullet *et al.*, p. 242, pl. 29, figs. 11 (text-fig. 2 in Conrad and Grábner, 1975), 12 (text-fig. 4 in Conrad and Grábner, 1975).
1986\. *Apinella hispanica* n. comb., Granier *et al.*, p. 804, not illustrated.
1994\. *Apinella hispanica*, Bucur, p. 151, pl. II, figs. 24–27.
1996\. *Apinella hispanica*, Granier and Deloffre, p. 26, not illustrated.
1996\. *Salpingoporella hispanica*, Sokač, p. 4-5, pl. V, figs. 1–8, 9 *pars*, 10 *pars*, 11 *pars.*
2000\. *Apinella hispanica*, Bucur *et al.*, p. 442, pl. VI, figs. 19–21.
2006\. *Salpingoporella hispanica*, Carras *et al.*, p. 476, pl. V, figs. 1 (text-fig. 2 in Conrad and Grábner, 1975), 2 (text-fig. 5 in Conrad and Grábner, 1975), 3 (text-fig. 3 in Conrad and Grábner, 1975), 4, 5 (pl. V, fig. 2 in Sokač, 1996).

Geographic and stratigraphic provenance. ?Senonian (or older as suggested here). Omoye Formation, Carumas section, Moquegua Region, South Peru. Previously this species was known only from the Hauterivian–lower Aptian interval (Table 1).

Discussion. Our Figure 2.1 compares well with the reconstruction of the algal thallus of "*Salpingoporella hispanica*" by Conrad and Grábner (1975, text-fig. 7). Figure 2.9 resembles a photomicrograph of Conrad and Grábner (1975, text-fig. 5). Sections of Figures 2.1 and 2.19 also concur with those illustrated in Conrad and Grábner (1975, text-figs. 2–3).

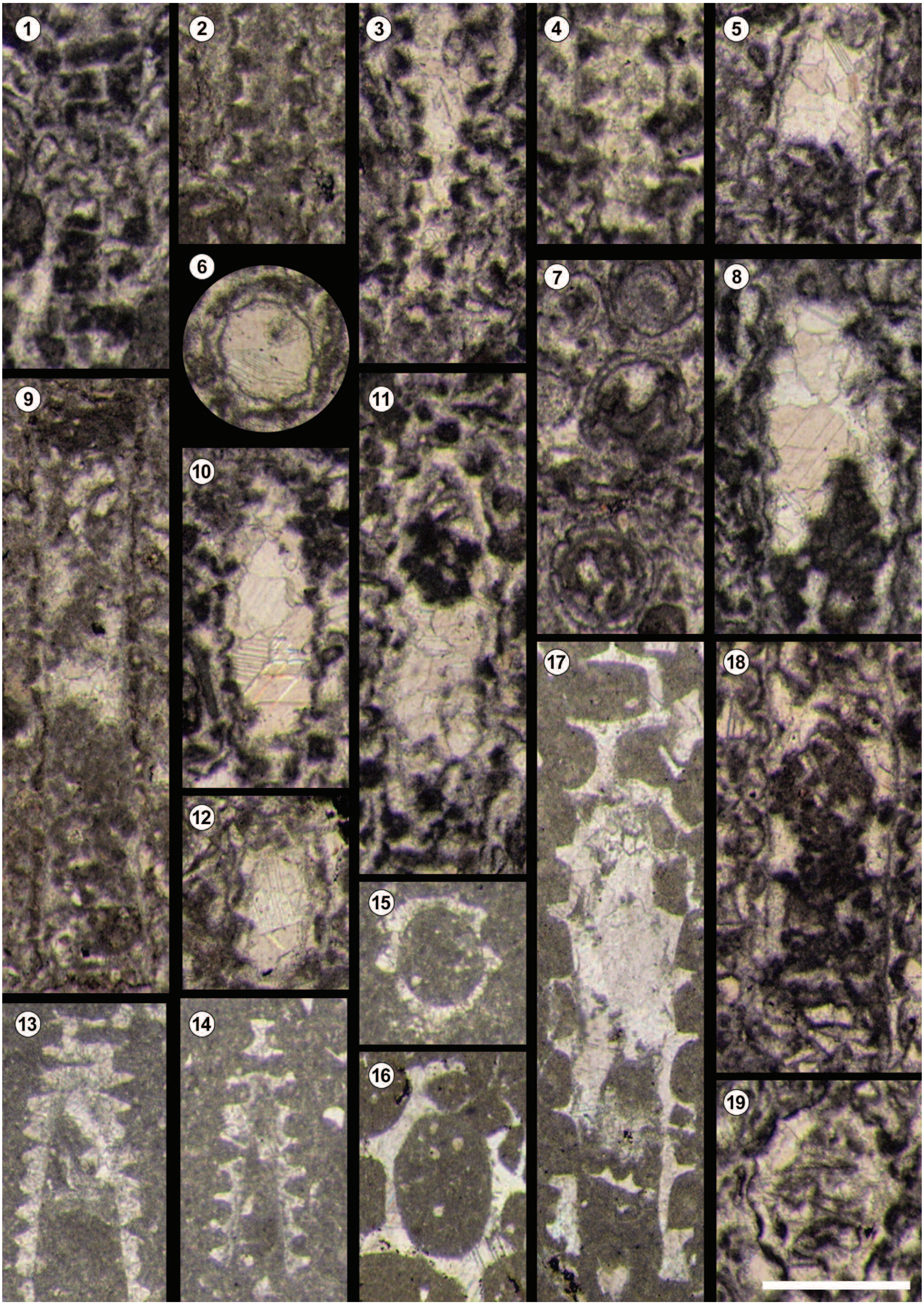
On the basis of 22 measurements, D = 380 ± 65 μm with D_{min} = 280 μm and D_{max} = 515 μm, *i.e.*, values that fall within the range given by Conrad and Grábner (1975): "0.25–0.46 mm"; d = 295 ± 55 μm with d_{min} = 205 μm and d_{max} = 420 μm, *i.e.*, values that also fall within the range given by Conrad and Grábner (1975): "0.16–0.36 mm"; the ratio d/D = 77 ± 6% with a minimum of 65% and a maximum of 85%, values that also fall within the range given by Conrad and Grábner (1975): "0.66–0.77"; note that the actual number of specimens measured by those authors was unspecified. In Figure 2.9, the specimen exceeds 2.1 mm in length. Moreover, we estimate that p_{max} should range from 185 to 280 μm with p_{min} ca. 30 μm. In Figure 2.1, the primary pores are ca. 260 μm in width. Similarly, h should range from 85 to 140 μm; in Figure 2.1, the verticils are 110 μm in height. Such values for height are slightly smaller than the range given by Conrad and Grábner (1975): "0.15–0.26 mm", but these authors might have overestimated these heights due to the scarcity of the sections and their obliquity. In our specimens, w varies from 4 to 6 although, according to Conrad and Grábner (1975), there should only be 4 laterals per verticil. We agree that their smaller specimens (Conrad and Grábner, 1975, text-figs. 4, 6.b–c) have 4 laterals per verticil but, in our opinion, their larger specimen (Conrad and Grábner, 1975, text-fig. 6.a) should have at least 5.

In conclusion, because these minor discrepancies are merely a matter of interpretation or because these variations may fall within the range of the natural variability of the species, they should not preclude identification of *Apinella hispanica* in our Peruvian material. However, because this species is so far known only from Barremian or Aptian strata, it could be argued that its occurrence in Senonian strata is striking, perhaps questionable. We



	Apinella jaffrezoi	Apinella hispanica	Salpingoporella hasi	Korkyrella *spp.*	Neomeris *spp.*	Trinocladus divnae	Marinella lugeoni
Maastrichtian					■		▨
Campanian					■		▨ unpublished
Santonian					■		▨
Coniacian					■		▨
Turonian					■		▨
Cenomanian			■	■	■	■	■
Albian			■	■	■	■	■
Aptian		■	■	■	■		■
Barremian		■		■	■		■
Hauterivian		■		?	■		■
Valanginian				?	■		■
Berriasian	?						■
Tithonian	■						■
Kimmeridgian	■						■

Table 1. Stratigraphic ranges of some taxa cited in the text.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elaborate further on this (below), under its companion species, *i.e.*, *Korkyrella* sp.

Genus ***Salpingoporella*** (Pia *in* Trauth, 1917)

Type species. *Diplopora Mülhbergii* Lorenz, 1902. Barremian of Switzerland.

Salpingoporella* ? *hasi Conrad *et al.*, 1976

Figure 4.4–9

1976. *Salpingoporella hasi* n. sp., Conrad *et al.*, p. 101–103, text-fig. 2, pl. I, figs. 1–10.
2006. *Salpingoporella hasi*, Carras *et al.*, p. 474-475, pl. IV, figs. 8 (pl. I, fig. 4 in Conrad *et al.*, 1976), 9 (pl. I, fig. 2 in Conrad *et al.*, 1976), 10 (pl. I, fig. 10 in Conrad *et al.*, 1976), 11 (pl. I, fig. 1 in Conrad *et al.*, 1976).
2006. *Salpingoporella hasi*, Radoičić, pl. 7, fig. 1.

Geographic and stratigraphic provenance. Cenomanian. Arcurquina Formation, Arcurquina section, Arequipa Region, South Peru. This species spans the upper Aptian–Cenomanian interval (Table 1).

Discussion. Our specimens of Figure 4.5–6 compare well with that of Radoičić (2006, pl. 7, fig. 1). On the basis of 8 measurements, D = 460 ± 75 µm with D_{min} = 345 µm and D_{max} = 590 µm, *i.e.*, values that fall within the range given by Conrad *et al.* (1976): "0.4–0.9" mm; d = 325 ± 55 µm with d_{min} = 260 µm and d_{max} = 420 µm, *i.e.*, values that also fall within the range given by Conrad *et al.* (1976): "0.24–0.64 mm". The ratio d/D = 71 ± 4% with a minimum of 62% and a maximum of 77%; otherwise some specimens of Conrad *et al.* (1976) are larger than our specimens. The known stratigraphic range of the species is in agreement with the Cenomanian age of these strata.

Family Dasycladaceae (Kützing, 1843)

Tribe unknown

Genus ***Korkyrella*** Sokač *et* Velić *ex* Sokač, 2004, non 1981

Type species. *Salpingoporella texana* Johnson *ex* Sokač, 2004, non 1965. Cenomanian of Texas.

Discussion. There is an ongoing dispute regarding the synonymy and the date of validity of this genus (Sokač and Velić, 1981; Conrad, 1982; Granier and Deloffre, 1993; Sokač, 2004). According to Conrad (1982), "*Salpingoporella texana* Johnson, 1965", is a *nomen nudum* that might eventually be included in the synonymy list of *Cylindroporella barnesii* Johnson, 1954. Unfortunately our Peruvian material is too poorly preserved to contribute to the debate.

Korkyrella sp.

Figure 6.1–10

Geographic and stratigraphic provenance. Same as *Apinella hispanica* (Conrad and Grábner, 1975), above. This genus ranges up to the Cenomanian; it is not clear whether its first occurrence is Valanginian, Hauterivian or Barremian.

Discussion. Some of our specimens (Fig. 6.1–2, 3 left) compare well with one section of *Cylindroporella barnesii* Johnson, 1954, as illustrated by Conrad (1982, pl. I, fig. 3). However, with D = 580 µm, that specimen is smaller than most of our specimens. Based on 20 measurements, we found that D = 700 ± 105 µm with D_{max} = 840 µm. These 20 values appreciably exceed the range cited by Johnson (1954) for *Cylindroporella barnesii*: "0.38 to 0.55 mm., average 0.375 mm.", but they conform with Sokač's (2004) range for *Korkyrella texana*: "0.52–1.46" mm.

The diameter of the axial cavity d = 615 ± 105 µm with d_{max} = 795 µm; the ratio d/D = 88 ± 4% with a minimum of 80% and a maximum of 94%. Few specimens possess a calcified (?) axis within the axial cavity (Fig. 6.4–5, 8–9); in this

Figure 2. 1–12, 18–19, *Apinella hispanica*; 1, tangential section, **OY**-137f (2); **2,** tangential section, **OY**-136c; **3,** tangential section, **OY**-137f (2); **4,** tangential section, **OY**-137f (2); **5,** oblique section, **OY**-137f (2); **6,** transverse section, **OY**-137f (3); **7,** transverse sections, **OY**-137f (1); **8,** ? oblique section, **OY**-137f (6); **9,** axial section, **OY**-136c; **10,** oblique section, **OY**-137f (6); **11,** long low-angle oblique (tangential to axial) section, **OY**-137f (2); **12,** oblique section, **OY**-137f (3); **18,** axial section, **OY**-137f (2); **19,** oblique section, **OY**-137f (6). **13–15, *Apinella urladanasi***, Aptian, France, Leg J. Pfender, no. 5 J8 "route de Riboux" 03/05/1935; **13,** long oblique section; **14,** long oblique section; **15,** subtransverse section. **16–17, *Apinella jaffrezoi***, Kimmeridgian, Guatemala, Leg F. Michaud, GA89-29; **16,** short oblique section; **17,** long low-angle oblique (tangential to axial) section. Scale bar= 500 µm.

case, the ratio d/D corresponds respectively to 61, 51, 56 and 44%. Such sections are similar to those documented by Sokač (2004, pl. XII, figs. 6–10). An alternative interpretation (Fig. 6.8–9) would be that two discrete algal pieces, a small calcareous coating and a larger one, mechanically imbricated during sedimentation.

According to Johnson (1965), his Texan species is Cenomanian in age. Sokač (2004) considered its range extends downward into the Albian, Aptian and Barremian stages.

Tribe Neomereae (Pia, 1920)

Genus ***Neomeris*** Lamouroux, 1816

Type species. *Neomeris dumetosa* Lamouroux, 1816; original designation (*op. cit.*, p. 241-243, pl. VII, fig. 8). Living species first collected in Antilles.

Neomeris spp.

Figures 4.10, 7.7–10

Geographic and stratigraphic provenance. Cenomanian. Respectively, Jumasha Formation, Oyón section, Lima Region, Central Peru (Fig. 4.10), and Arcurquina Formation, Arcurquina section, Arequipa Region, South Peru (Fig. 7.7–10). There are still living *Neomeris*, but the first record would be as old as the Valanginian (Table 1).

Discussion. Most *Neomeris*-like remains found in Cretaceous strata were commonly reported as *Neomeris cretacea* Steinmann, 1899. Successive revisions by Barattolo (1990) and Sokač (2004) have shown that such ascriptions are generally erroneous. Our material is not attributable to any known species, and is insufficiently abundant to permit a new specific designation.

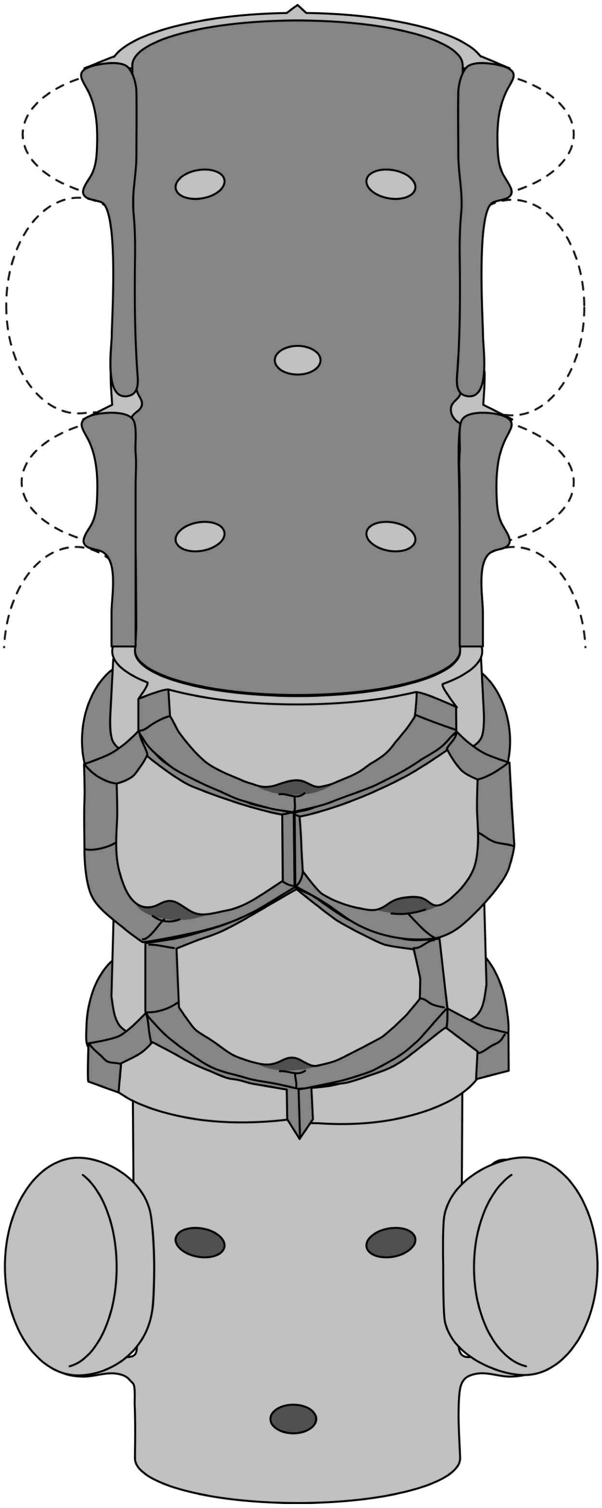
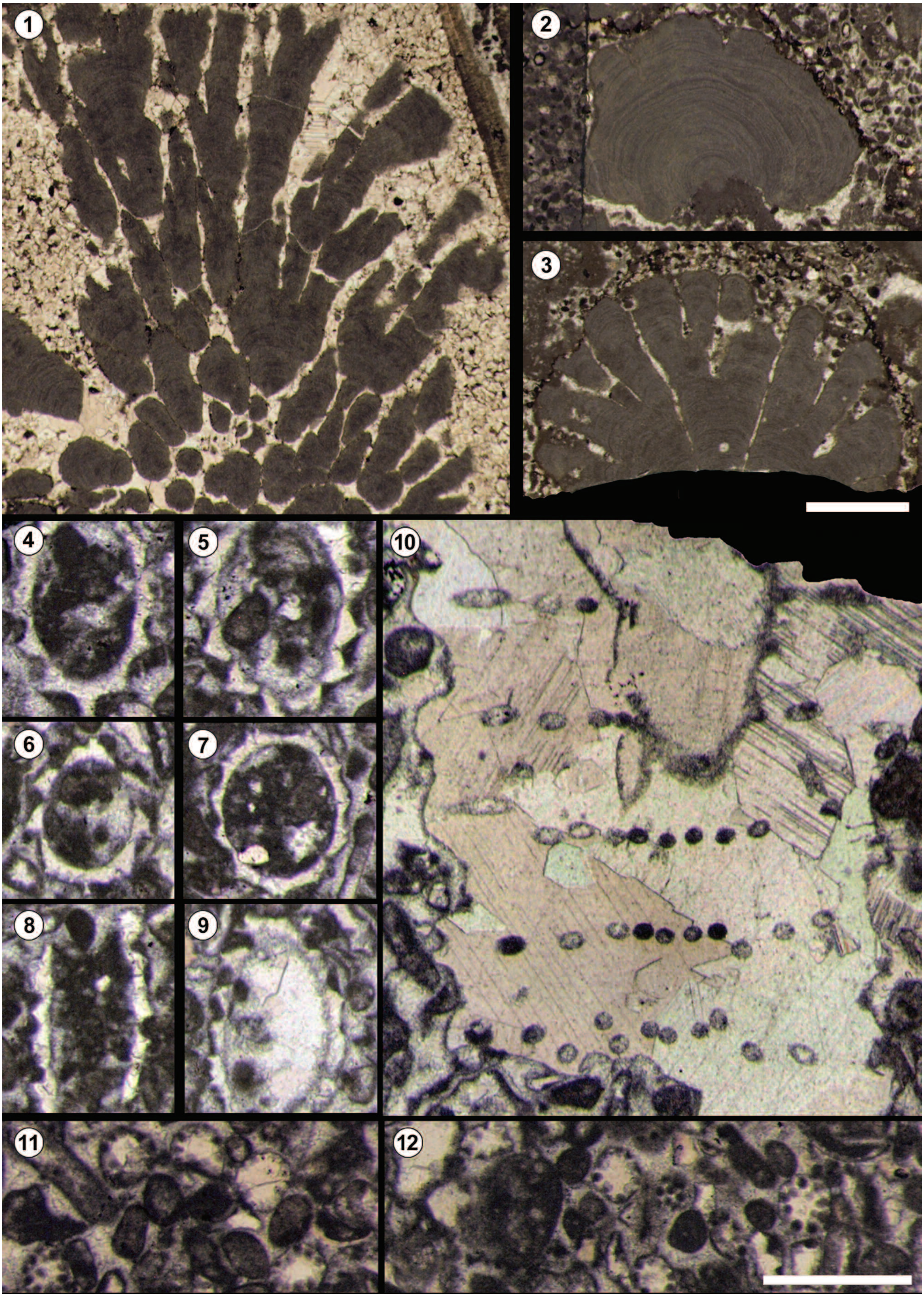


Figure 3. 1–3, Reconstruction of ***Apinella jaffrezoi*** (modified after Granier *et al.*, 1986) ; **1,** section of the calcified thallus; **2,** calcified thallus; **3,** uncalcified thallus.

Figure 4. 1–3, ***Marinella lugeoni***, **JU**-101a (2); **1,** random section of a branching morphotype; **2,** longitudinal section of a massive morphotype; **3,** longitudinal section of a branching morphotype. **4–9,** ***Salpingoporella? hasi***; **4,** oblique section, **AC**-55 (2); **5,** oblique section, **AC**-55 (2); **6,** subtransverse section, **AC**-55 (2); **7,** subtransverse section, **AC**-55 (2); **8,** oblique section, **AC**-55 (3); **9,** oblique section, **AC**-55 (2). **10,** ***Neomeris*** sp.; oblique section, **AC**-55 (2). **11–12,** ***Terquemella*** sp.; **11,** random sections, **AC**-55 (1); **12**, random sections, **AC**-55 (2). Scale bars= 1 mm (1–3) and 500 µm (4–12).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Family ? Thyrsoporellaceae Granier *et* Bucur *in* Granier *et al.*, 2012

Tribe ? Thyrsoporelleae (Pia *in* Hirmer, 1927)

Genus ***Trinocladus*** Raineri, 1922

Type species. *Trinocladus tripolitanus* Raineri, 1922; original designation. Cenomanian of Libya.

Trinocladus divnae Radoičić, 2006

Figure 7.1–5, 11–12

2006. *Trinocladus divnae*, n. sp., Radoičić, p. 66-68, text-fig. 2, pl. 1, figs. 1–14; pl. 2, figs. 1–8; pl. 3, figs. 1–6.

Geographic and stratigraphic provenance. Cenomanian. Jumasha Group, Oyón section, Lima Region, Peru. Its type locality is in Albian–Cenomanian strata (Table 1).

Discussion. According to its author (Radoičić, 2006), "this species resembles *Trinocladus tripolitanus* Raineri" that "is not so variable in the size of the thallus". In other words, *T. divnae* has a claviform (*i.e.*, "club") shape, whereas *T. tripolitanus* is cylindrical.

On the basis of 9 measurements, D = 670 ± 140 µm with D_{min} = 430 µm and D_{max} = 860 µm. Outer diameters of the small specimens fall within the range of *T. tripolitanus* given by Raineri (1922): "*fra µ 504 e µ 750*" (*i.e.*, 504 to 750 µm), and those of the large specimens are within the range of *T. divnae* cited by Radoičić (2006): "0.710–1.640" mm. We have only three measurements for the inner diameter, *i.e.*, d = 160, 195, and 225 µm, to compare with "*massimo di µ 135*" for *T. tripolitanus* according to Raineri (1922) and "0.126–0.177" mm for *T. divnae* (q.v. Radoičić, 2006).

Our specimens come from the Jumasha Group of Central Peru; the Cenomanian age of the Jumasha strata concurs with the known stratigraphic ranges of both species.

Family Bornetellaceae Granier *et* Bucur *in* Granier *et al.*, 2013

Tribe Bornetelleae (L. Morellet *et* J. Morellet, 1913)

(Organo-) Genus ***Terquemella*** Munier-Chalmas *ex* L. Morellet *et* J. Morellet, 1913

Type species. *Terquemella parisiensis* Munier-Chalmas *ex* L. Morellet *et* J. Morellet, 1913. Eocene of France.

Terquemella spp.

Figure 4.11–12

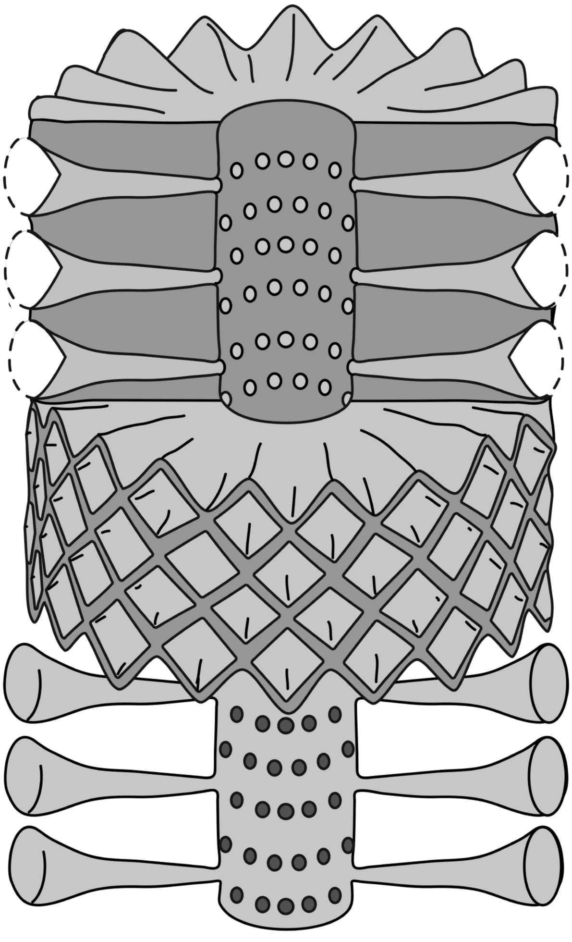
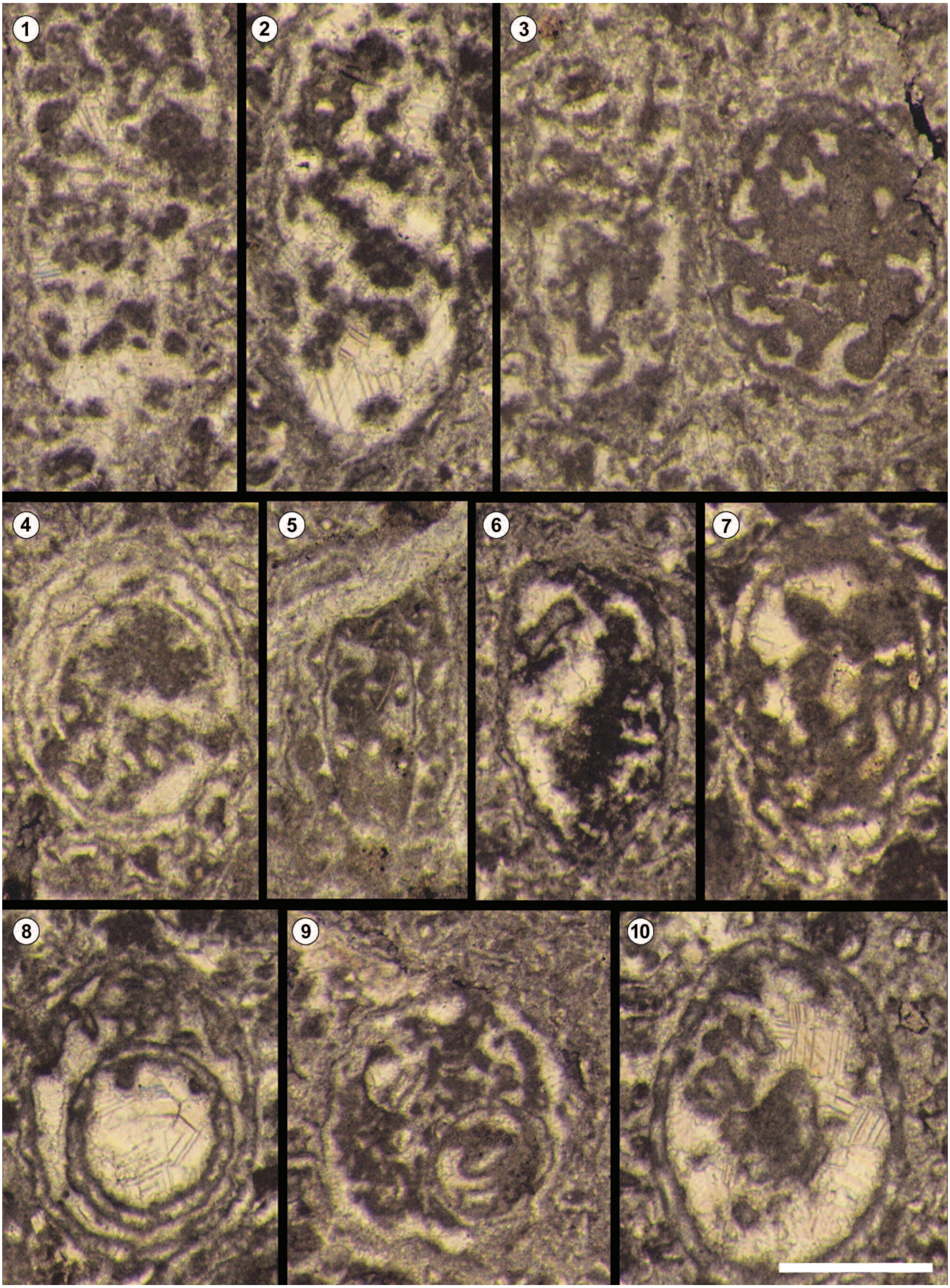


Figure 5. 1–3, Reconstruction of a ***Salpingoporella*** with typical phloiophorous pores (*i.e.*, the pore diameter increases rather gradually outward); **1,** section of the calcified thallus; **2,** calcified thallus; **3,** uncalcified thallus.

Figure 6. 1–10, *Korkyrella* sp.; **1,** oblique section, **OY**-137f (1); **2,** oblique section, **OY**-137f (5); **3,** oblique section and subtransverse section, **OY**-137f (1); **4,** oblique section with a double bell, **OY**-137f (3); **5,** oblique section with a double bell, **OY**-136c; **6,** oblique section, **OY**-137f (2); **7,** oblique section, **OY**-137f (5); **8,** subtransverse section with a double bell or imbricated sections, **OY**-137f (4); **9,** ?imbricated sections, **OY**-137f (1); **10,** oblique section, **OY**-137f (2). Scale bar= 500 µm.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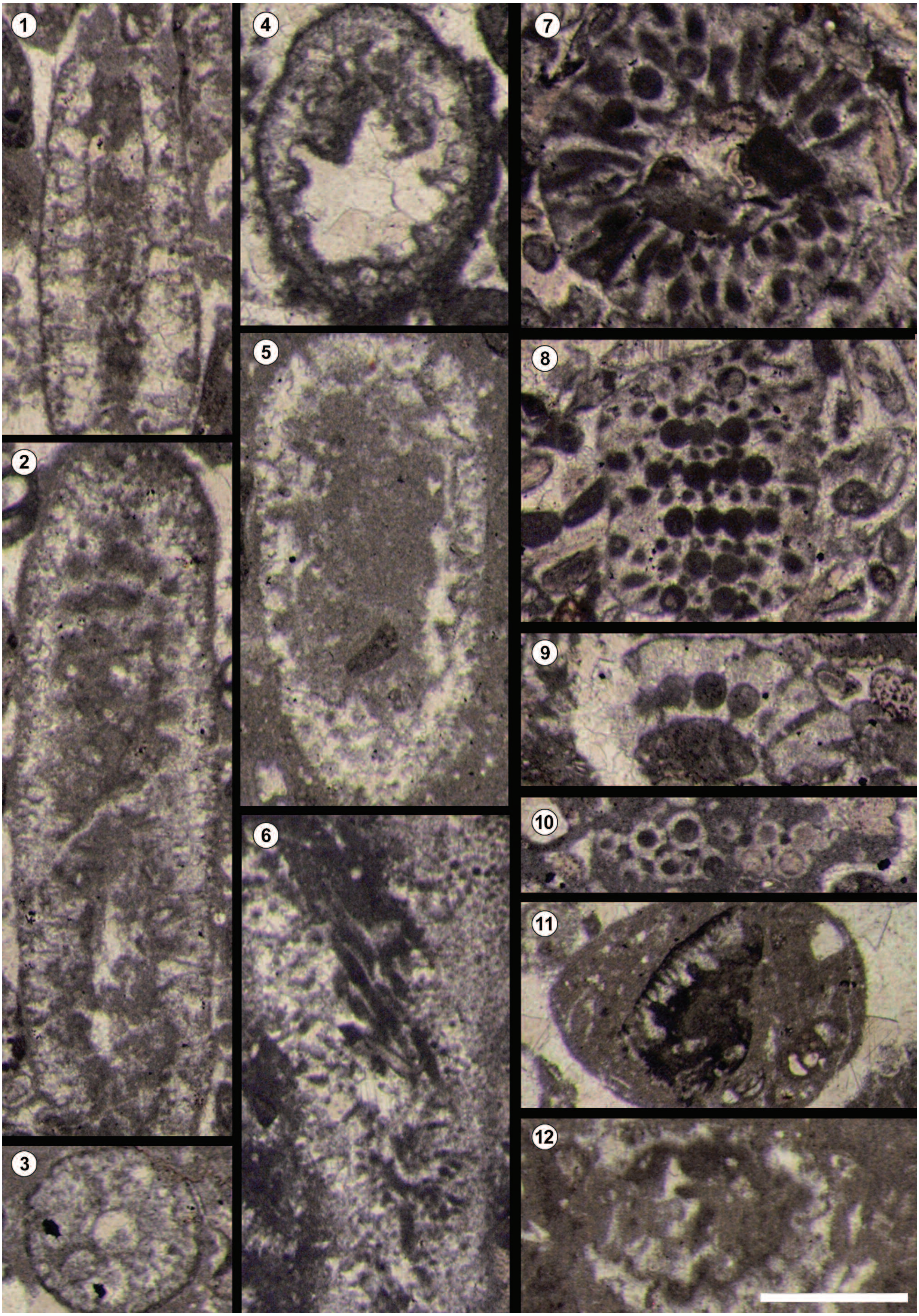
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Geographic and stratigraphic provenance. Hauterivian–Aptian and Cenomanian. Respectively, Huancané Formation, Goyllarisquizga Group, Carumas section, Moquegua Region, South Peru, and Arcurquina Formation, Arcurquina section, Arequipa Region, South Peru (Fig. 4.11–12).

Discussion. The organogenus *Terquemella* corresponds to rounded aggregates of cysts, which might have originally been sited on the side of primary laterals of a poorly or non-calcified alga. The Carumas specimens reach 160 µm in diameter with 10 cysts, each ca. 20 µm in diameter, regularly arranged peripherally in the largest sections, *i.e.*, an estimated 30 cysts per aggregate. The Arcurquina specimens are larger: they reach 250 µm in diameter with 15 cysts, each ca. 30 µm in diameter, regularly arranged peripherally in the largest sections, *i.e.*, an estimated 40 cysts per aggregate.

Phylum RHODOPHYTA (Wettstein, 1901)
Class FLORIDEOPHYCEAE Cronquist, 1960
Subclass CORALLINOPHYCIDAE Le Gall *et* Saunders, 2007
Order ? RHODOGORGONALES Fredericq *et* Norris, 1995
Family ELIANELLACEAE Granier *in* Granier *et* Dias-Brito, 2016

Genus ***Marinella*** Pfender, 1939

Type species. *Marinella lugeoni* Pfender, 1939; *nomen conservandum*. Kimmeridgian of Spain (Granier and Dias-Brito, 2016b).

Marinella lugeoni Pfender, 1939
Figure 4.1–3

Geographic and stratigraphic provenance. Hauterivian–Aptian. Huancané Formation, Goyllarisquizga Group, Carumas section, Moquegua Region, South Peru.

Discussion. Its original French description (Pfender, 1939) was recently translated into a slightly modified English version (Granier and Dias-Brito, 2016b): “It is probably a filamentous alga, (…) zoned with the H. Derville’s ‘puff of pipe smoke’ type (…). The thallus consists of juxtaposed filaments” with both cross partitions and constrictions; they frequently vary in direction, while remaining radiating, never curled up. The fabric looks hairy rather than forming a lattice. The whole thing forms a finger thallus, notched, fan-shaped, dark, because the diameter of the tube-like filaments is very small, usually 6 to 9 µ (…). The constrictions within the filaments are often at the same level and form concentric lines on the thallus (…). Transverse sections of juxtaposed tubes are either polygonal or rounded and apparently may slightly vary in size, with a diameter of 9 µ in average. These thalli are readily identifiable in the thin sections where they appear darker, being formed of a denser, more regular fabric, which is not concentrically oriented like the *Girvanella* filaments.” In our Peruvian material, various morphotypes coexist: for instance, we observed a massive morphotype (Fig. 4.2) next to branching morphotypes (Fig. 4.1, 3). Accordingly, it is clear that growth morphology should not be used to segregate species within the genus *Marinella*. Only one species was said to span the Kimmeridgian–Cenomanian interval until the recent finding in Eocene strata of the Foz do Amazonas, Brazil (Granier and Dias-Brito, personal communication, 2017/04/28).

CONCLUSIONS

This paper reports the first occurrences of calcareous algae from Cretaceous strata of Peru: *Salpingoporella* ? *hasi*, *Trinocladus divnae*, *Neomeris* spp., and *Terquemella* spp. from Cenomanian strata; *Apinella hispanica* and *Korkyrella* sp., first ascribed to the Senonian, but possibly Cenomanian or even older strata;the calcareous red alga *Marinella lugeoni* and *Terquemella* spp. from Early Cretaceous, possibly Valanginian strata.

Southernmost occurrences of calcareous algae can be expected in Chile, more precisely in the Atacama Region

Figure 7. 1–5, 11–12, *Trinocladus divnae*, **JU**-63; **1,** subaxial section; **2,** long low-angle oblique (tangential to axial) section; **3,** transverse section; **4,** oblique section; **5,** oblique section; **11,** random section in a small coated lithoclasts; **12,** oblique section. **6, *Halimeda*** sp., **JU**-212; random section of a large article. **7–10, *Neomeris*** spp.; **7,** subtransverse section, **JU**-45 (1); **8,** tangential section, **JU**-45 (2); **9,** oblique section of a single whorl, **JU**-45 (3); **10,** tangential section, **JU**-51. Scale bar= 500 µm.

(north Chile); and possibly in the Coquimbo Region (central Chile) in upper Aptian–lower Albian strata, whence d'Orbigny (1842a, 1842b) discovered the rudist "*Hippurites chilense*", recently resurrected from oblivion thanks to Mourgues *et al.* (2010) and Masse *et al.* (2015). Besides these rudists – indicative of chlorozoan tropical associations – some calcareous green algal remains would likely be discovered and we would welcome opportunities to access such material for study and inclusion in our database.

ACKNOWLEDGEMENTS

Special thanks go to J.-J. Fleury who kindly identified some rare foraminifers, including *Archaias* (*Perouvianella*) *peruviana* (Steinmann, 1929). The French Institute for Andean Studies (IFEA) and the Research Institute for Development (IRD) are thanked for funding field work.

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doi: 10.5710/AMGH.17.07.2017.3093

Submitted: February 6th, 2017

Accepted: July 17th, 2017