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Upper Aptian calcareous algae from Pădurea Craiului (Northern Apuseni Mountains, Romania)

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Geologia Croatica

ABSTRACT

A study of calcareous strata previously assigned to the Barremian-Early Aptian interval in the northwestern part of Pădurea Craiului, (Apuseni Mountains), led to the identification of a micropaleontological association indicative of a Late Aptian age. Unequivocal evidence for the Late Aptian assignment of these limestones is the presence throughout the sequence of two orbitolinid species, Mesorbitolina texana *(ROEMER) and* Mesorbitolina subconcava *(LEYMERIE). The most interesting sections are located in the neighbourhood of Subpiatră, where both outcrops and a quarry facilitated detailed analyses. In this area, the Upper Aptian succession consists basically of three types of macrofacies: 1) limestone with rudists; 2) limestone with* Bacinella *and 3) limestone with corals, each of them showing several types of microfacies.* Bacinella *structures are the most common feature in the whole succession, irrespective of the macrofacies. This paper focuses on an algal association that was identified in several levels within the succession. Dasycladalean algae are more frequent, and are commonly found in grain-dominated fabrics (mostly grainstone textures), in association with orbitolinid foraminifera and bioclasts of corals, rudists and gastropods. However, a few species are present only in mud-dominated fabrics (i.e. lower-energy intervals).*
The dasycladalean association from the Upper Aptian deposits of Pădurea Craiului is of special interest, for this group registered a dramatic decline at the Lower Aptian/Upper Aptian boundary, as confirmed by the relative scarcity of the Dasycladales in the Upper Aptian carbonate deposits.

Keywords: calcareous algae, Upper Aptian, Pădurea Craiului, Apuseni Mountains, Romania

1. INTRODUCTION, STRATIGRAPHIC FRAMEWORK

The Pădurea Craiului Massif includes Mesozoic deposits of Triassic, Jurassic and Cretaceous age. Samples were collected from several profiles in the Subpiatră quarry (near the Aleşd locality, in the northwestern part of the Pădurea Craiului Mountains (Fig. 1) and were assigned into the local Cretaceous succession. The lowermost Cretaceous strata lie unconformably on a surface deformed by regional uplift at the end of the Upper Jurassic. The sequence begins with bauxites that are overlain by carbonate deposits assigned to discrete lithostratigraphic units, from bottom to top as follows (Fig. 2):

1) **Blid Formation** (DRAGASTAN et al., 1986, 1988). This formation includes two members (COCIUBA, 2000):
   1. a) The Dobreşti Member overlies bauxites or rests directly on Upper Jurassic limestone. Originally, the basal limestone of the Dobreşti Member contains lacustrine deposits, which are followed by brackish and finally by normal marine strata; in the literature they are known as “Limestone with characeans and gastropods” (PATRULIUS in IANOVICI et al., 1976). Besides characeans and gastropods, this limestone contains dasycladalean algae and foraminifera, an assemblage

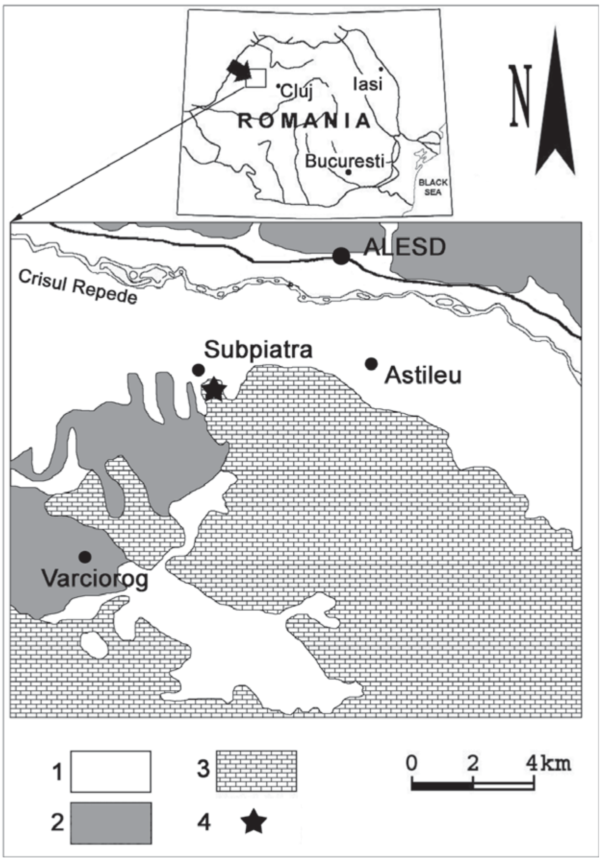

Figure 1: Location of the study area. 1 Quaternary deposits; 2 Cenozoic deposits; 3 Mesozoic deposits; 4 Location of the studied section (Subpiatră Quarry).

with a low value regarding its stratigraphic resolution that however indicates a Berriasian–Hauterivian range.

1. b) The Coposeni Member, previously known as the "Lower pachyodont limestone" (PATRULIUS in IANOVICI et al., 1976), is Upper Hauterivian-Barremian in age. The foraminiferal association identified in the lower-middle part of this limestone contains *Paracoskinolina*? *jourdanensis* (FOURY & MOULLADE), an index foraminifer for the Upper Hauterivian p.p. and Lower Barremian.

2) **Ecleja Formation** (PATRULIUS, in IANOVICI et al., 1976), a succession of greyish silty marls to marly silts. It includes two members that differ in lithology from the marly succession (COCIUBA, 2000):

2. a) The Gugu Breccia Member (PATRULIUS et al., 1982) and

2. b) The Valea Bobdei Limestone Member (COCIUBA, 2000). The Valea Bobdei limestone was known previously as "The middle pachyodont limestone". Most probably, its age is basal Early Aptian (early Bedoulian).

3) The **Valea Măgurii Limestone Formation** (COCIUBA, 2000) rests on the Ecleja Marls and its upper limit is the site of an unconformity. This formation is also of Early Aptian age (most probably late Bedoulian). Both the Valea Bobdei Limestone and the Valea Măgurii Limestone include the orbitolinid *Palorbitolina lenticularis* (BLUMENBACH), a fossil that ranges from the Late Barremian to the Early Aptian.

4) The **Vârciorog Formation** (COCIUBA, 2000) is the new designation for the previously defined "Formation of the glauconitic sandstones and the upper pachyodont limestones" (PATRULIUS in IANOVICI et al., 1976). In the Varciorog area, the limestone interbeds are 15–20 m thick and contain *Mesorbitolina texana*. The Vârciorog Formation was assigned to the Upper Aptian (Gargasian) – Albian interval. The limestone of the Subpiatră quarry belongs to this same formation. A section in the southern part of the study area was the object of a preliminary investigation (DAOUD *et al.*, 2004).

2. CARBONATE FACIES AND AGE OF THE VÂRCIOROG FORMATION LIMESTONE

Macroscopically, three major facies could be identified: biostromes with rudists, limestone with *Bacinella* nodules and coral bioconstructions with their associated unique facies (Fig. 3). Their study under the microscope showed several types of microfacies all characterized by an abundance of *Bacinella,* (its occurrence is most conspicuous in a bindstone with *Bacinella,* and in a bioclastic wackestone-packstone with *Bacinella* oncoids), followed by somewhat lesser quantities in wackestone-packstone and coarse bioclastic grainstone, packstone and boundstone with rudists, coral boundstone and peloidal-bioclastic wackestone-packstone (Pl. 1, Figs. 1–7). *Bacinella* is the main component in all of these microfacies; it represents more than 30 % of the total volume.

The micropalaeontological associations in the whole succession include both foraminifera and algae. The following have been identified: *Sabaudia minuta* (HOFKER), *Sabaudia auruncensis* CHIOCCHINI & DI NAPOLI ALIATA, *Glomospira urgoniana* ARNAUD-VANNEAU, *Troglotella incrustans* WERNLI & FOOKES, *Mesorbitolina texana* (ROEMER) (Pl. 2, Fig. 1), *Mesorbitolina subconcava* (LEYMERIE) (Pl. 2 fig. 2), *Pseudolituonella conica* LUPERTO SINNI & MASSE, *Girariarella? prismatica* ARNAUD-VANNEAU. The two species of *Mesorbitolina (M. texana* and *M. subconcava*) in this association have a particular significance for their range does not extend downward to the Gargasian (middle Aptian). Limestone beds of the same age, which were previously assigned to the so-called "Upper pachyodont limestone", are also known at Varciorog where they are included in the Vârciorog Formation. At this location, these beds are interbedded with coarse siliciclastics. They do not exceed 15–20 m in thickness and show clear evidence of gravitational flow. In the Subpiatră quarry, the age equivalent limestone beds are120–150 m-thick and are typical carbonate platform deposits. Presumably, the carbonate succession in the Subpiatră quarry area represents the Upper Aptian carbonate platform that provided the gravitational flows found in the Vârciorog area where terrigenous deposits with a "flysch-like" character predominate.

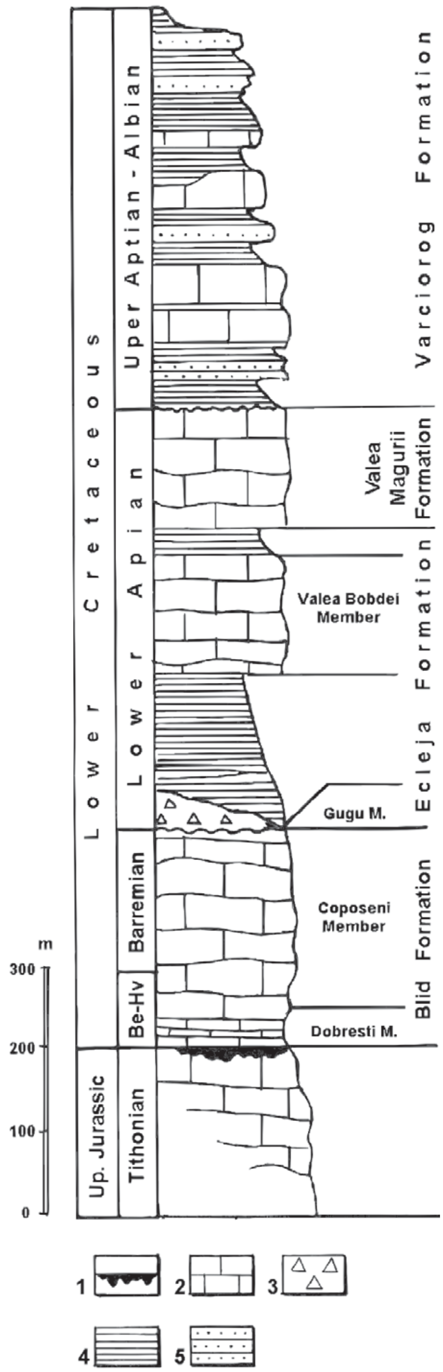

Figure 2: Lower Cretaceous lithostratigraphic units from the Pădurea Craiului Mountains. 1 Bauxite; 2 Limestone; 3 Breccia; 4 Marl and shale; 5 Sandstone

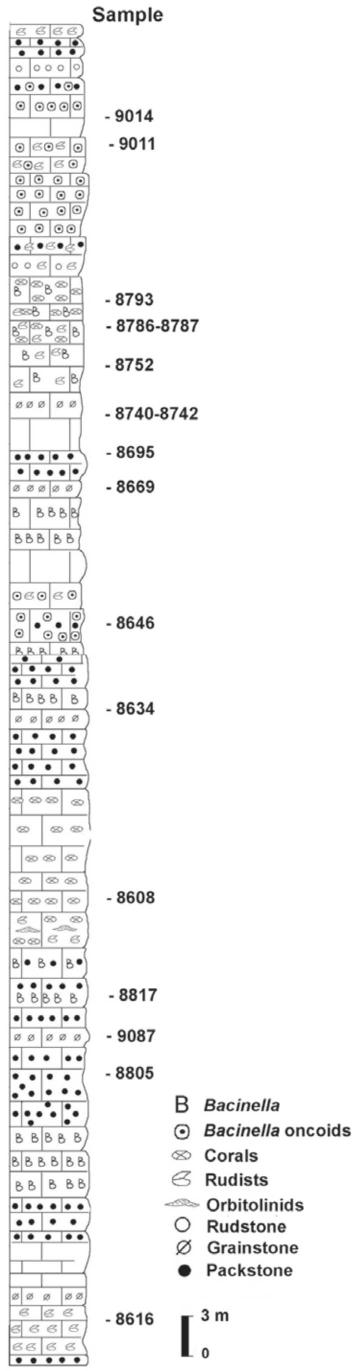

Figure 3: Succession and facies characteristics of the Upper Aptian limestones from the Subpiatră Quarry, with the location of algae-bearing samples

3. THE CALCAREOUS ALGAE

An algal association was identified at several levels in the succession. It is dominated by dasycladalean algae and it consists of: *Anisoporella*? *cretacea* (DRAGASTAN), *Cylindroporella ivanovici* (SOKAČ),?*Clypeina* sp., *Dissocladella* sp., *Neomeris* sp., *Russoella* sp., *Salpingoporella* sp., *Terquemella* sp., *Triploporella* sp., *Zittelina* sp. and the microproblematicum *Coptocampylodon fontis* PATRULIUS. It includes other algal groups represented by *Polystrata alba* PFENDER, *Parachaetetes asvapatii* (PIA) and rivulariacean-type cyanobacteria.

Anisoporella? *cretacea* (DRAGASTAN, 1967)

(Pl. 3, Fig. 7)

This alga was originally described from the Pădurea Craiului area (Apuseni Mountains) as *Pseudoepimastopora cretacea* (DRAGASTAN, 1967). Following its emendation to the genus *Pseudoepimastopora* (ROUX, 1979) and its subsequent invalidation (GRANIER & DELOFFRE, 1993), the alga was assigned to two other genera: *Epimastoporella* ROUX 1979 (BUCUR, 1992) and *Anisoporella* BOTTERON 1961 (BUCUR, 1995) (see BUCUR, 2000 for a detailed discussion of

PLATE 1

1 Bioclastic-intraclastic rudstone with large coral fragments, rudist, bivalve, gastropod and echinid fragments, and foraminifera; 8608.

2 Coarse bioclastic packstone with gastropods and dasycladales; 9087.

3–4 Subtidal limestones formed in a high hydrodynamic environment and subsequently subaerially exposed. Stalactitic-type cement (fig. 3, arrows) and meniscus-type cement (fig. 4) indicating vadose diagenesis. The intergranular voids are filled with ostracod- and small gastropod-bearing ooze, and microbialite. Fig. **3**, 8869; Fig. **4**, 8865.

5 Limestone with *Bacinella*; 8817.

6 Coral bioconstructions, 8646.

7 Vertical succession of facies of different grain-size within peritidal deposits. The subtidal deposits formed in a high energy environment (lower part) are intercalated with subtidal deposits formed in a low-energy environment (upper part); 8793.

Scale bar is 1 mm for all figures.

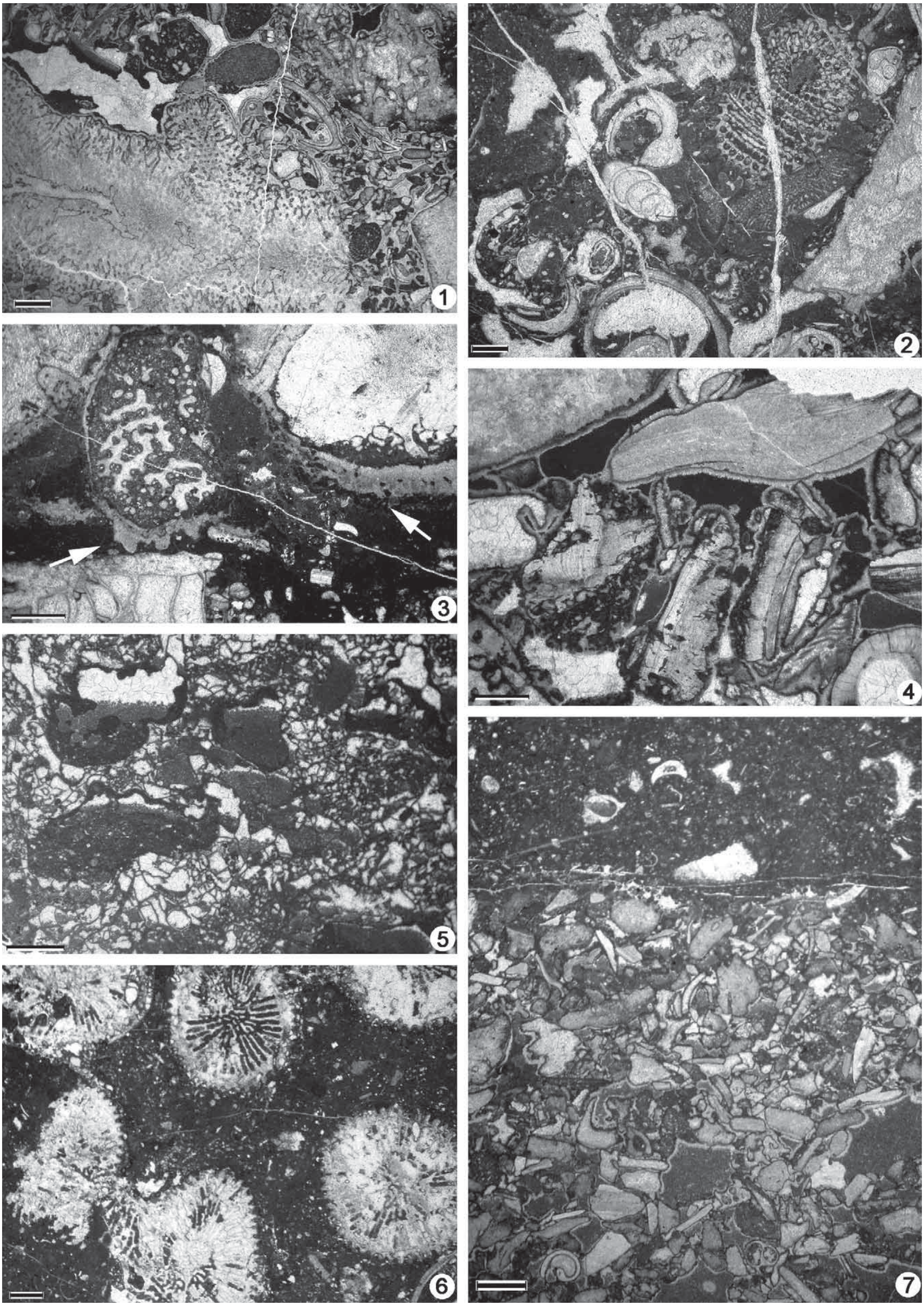
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PLATE 2

1 *Mesorbitolina texana* (RÖMER); 8634.

2 *Mesorbitolina subconcava* (LEYMERIE); 8805.

3 *Coptocampylodon fontis* PATRULIUS and *Terquemella* sp.; 9011.

4 *Polystrata alba* (PFENDER); 8669.

5–6 Rivulariacean-type cyanobacteria. Fig. **5**, 9014; Fig. **6**, 8695

7 *Parachaetetes asvapatii* PIA; 8069.

8 *Terquemella* sp.; 8616.

Scale bar is: 0.125 mm (Fig. 4); 0.25 mm (Figs. 1 and 2); 0.5 mm (Figs. 3, 5–8)

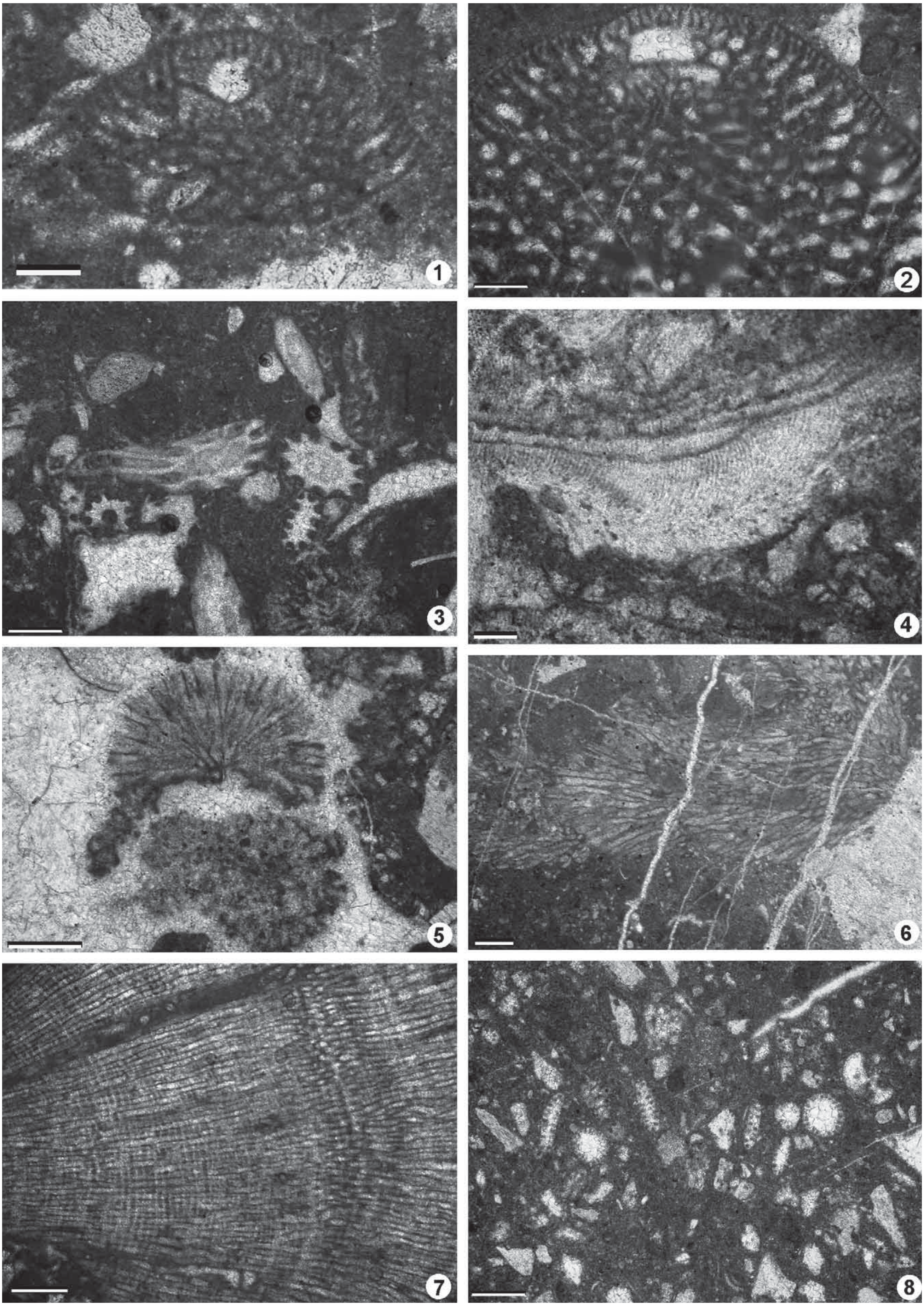
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PLATE 3

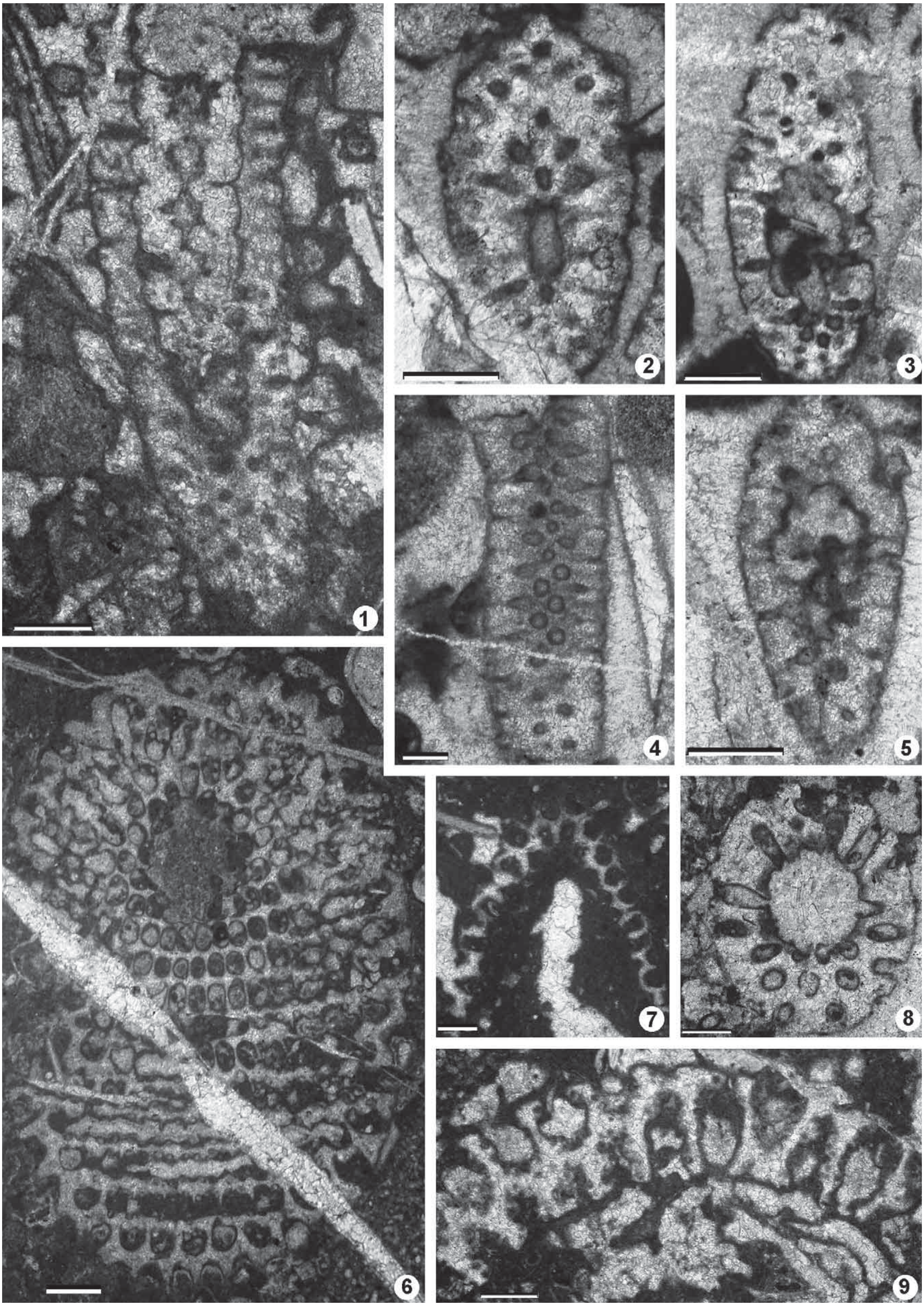
1–5 *Cylindroporella ivanovici* (SOKAČ). Fig. **1**, 8742; Figs. **2**, **3**, **5**, 8687; Fig. **4**, 8686.

6, 9 *Zittelina* sp. Fig. **6**, 9087; Fig. **9**, 8742.

7 *Anisoporella*? *cretacea* (DRAGASTAN), 8752.

8 *Triploporella* sp.; 8740.

Scale bar is: 0.25 mm (Fig. 4); 0.5 mm (Figs. 1–3, 5–9).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synonymies and generic assignment). In fact as shown by RADOIČIĆ (2005), the affiliation of the species *A.*? *cretacea* to the genus *Anisoporella* was incorrect, *Anisoporella*-type algae have vesiculiform laterals in a euspondyl arrangement, but with double verticils (a feature not present in *A.*? *cretacea*, which has simple euspondyl verticils). As noted by BUCUR *et al*. (2005), the morphological features of the skeleton of this alga are closer to those of the genus *Griphoporella* as described and emended by BARATTOLO et al. (1993). Most probably, *Epimastopora cekici* RADOIČIĆ (Upper Hauterivian – Lower Barremian) and *Gyroporella lukicae* SOKAČ & VELIĆ (Lower Aptian) are ascribable to the same genus. The clarification of the systematic status of *Anisoporella? cretacea* is in progress, based on new finds in the Jurassic and Lower Cretaceous deposits of the Alps and the Carpathians (BUCUR & SCHLAGINTWEIT, in prep.).

Generalised stratigraphic range: Oxfordian–Aptian.

Cylindroporella ivanovici (SOKAČ, 1987)
(Pl. 3, Figs. 1–5)

This dasycladalean alga is the most common species in our samples. Here too, the systematic assignment has undergone several changes. It was originally described as a species of the genus *Korkyrella* SOKAČ & VELIĆ, 1981 (SOKAČ, 1987), which was subsequently invalidated because the type species, originally named *Salpingoporella texana*, was considered to be invalid. The species *K. ivanovici* has also been considered a junior synonym of the species *Pseudoepimastopora pedunculata* JAFFREZO et al., 1980 (in the new combination *Cylindroporella pedunculata*, see LUPERTO SINNI & MASSE, 1993; BODROGI et al., 1994; BUCUR, 2000; SOTAK & MIŠIK, 1993) or it has been transferred to the genus *Cylindroporella* (*C. ivanovici)* (see MANCINELLI, 1992; MASSE & ISINTEK, 2000). SOKAČ (2004) has revised the genus *Korkyrella* by designating a lectotype for *Salpingoporella texana* JOHNSON, 1965 and has redefined the species *Korkyrella texana* (a taxonomic procedure that may cause a homonymy thus leading to another invalidation of the genus *Korkyrella*). The relationship between *Cylindroporella ivanovici* and *Cylindroporella barnesii* JOHNSON (1954), has been discussed by BUCUR (2000), who shows that often the two species have been distinguished on the basis of "stratigraphic" criteria and may represent, in fact, a single species (see also CONRAD, 1982). But to confirm this, a careful review of the type species would be required. *Griphoporella aurigerica* CONRAD & PEYBERNES (1976) may be another synonym of this species.

Generalised stratigraphic range: Hauterivian–Albian

Terquemella sp.
(Pl. 2, Figs. 3pars, 8)

A number of small objects in association with fossil algae have been described in the palaeoalgological literature and named either *Acicularia*, or *Terquemella*, both considered as the reproductive bodies (gametophores) of some dasycladales in deposits of Late Jurassic – Early Creataceous age (*e.g. Terquemella antiqua*, PIA, 1936; *Acicularia elongata*, CAROZZI, 1947; *Acicularia jurassica*, JOHNSON, 1961; *Acicularia americana*, KONISHI & EPIS, 1962; *Acicularia endoi*, PRATURLON, 1964; *Acicularia intermedia*, DRAGASTAN, 1967; *Terquemella concava*, BERNIER, 1979). As a rule, the assignment of these objects to either one of the two organogenera was based on ambiguous or subjective criteria. Most of them have been assigned to the genus *Acicularia*. However, some have been reconsidered and assigned to the genus *Terquemella* (e.g. *T. endoi* and *T. antiqua*, see MASSE, 1995; MASSE & ARNAUD-VANNEAU, 1999). Here again a complete review is needed to clarify the taxonomy of the group. In our opinion, there is a simple and efficient morphological criterion that may be used to differentiate the two genera: the presence of "club-shaped" longitudinal sections clearly links the gametophores' construction to the reproductive disk of *Acicularia* (e.g. *Acicularia* sp., KUSS & HERBIG, 1993). If the shape is spheroidal, ovoidal or discoid an affiliation with the genus *Terquemella* is much more probable. This distinction is obvious when a large number of specimens are found in one sample (fossil assemblage), as is the case of the Upper Aptian limestone samples from Pădurea Craiului: they show discoid morphologies. The specimens illustrated in Pl. 2, fig. 8 represent, most probably, a new species.

Zittelina sp.
(Pl. 3, Figs. 6, 9)

The genus *Zittelina* is represented in Lower Cretaceous deposits by only one species (*Zittelina hispanica* MASSE et al., 1993) that was identified first in the Hauterivian of Spain and then recorded in the Barremian-Aptian deposits of the Reşiţa Zone (Southern Carpathians, Romania, cf. BUCUR, 2001). However, the specimens identified in the Upper Aptian of the Pădurea Craiului area differ from *Zittelina hispanica* in several morphological and dimensional parameters, so they may be a separate new species. Similar specimens have been illustrated by CAMOIN (1982, pl. 1, figs. 2–3) under the name *Triploporella* cf. *decastroi* and *Triploporella* cf. *matesina* from Barremian-Aptian deposits in Sicily. MASSE & ARNAUD-VANNEAU (1995) have also illustrated *Zittelina* sp. from Albian deposits on a "guyot" of the northwestern Pacific Ocean. These authors consider their specimen to be a new species. It is similar to the form we described from Pădurea Craiului. The study of this alga is in progress based on additional material recently collected from the Subpiatră quarry (Pădurea Craiului).

We have identified several other dasycladalean algae from single specimens or from a limited numbers of specimens, so these sparsely represented forms have been assigned only at the generic level (?*Clypeina* sp., *Dissocladella* sp., *Neomeris* sp. – most probably a fragment of *Neomeris cretacea*, *Russoella* sp., *Salpingoporella* sp., *Triploporella* sp. – Pl. 3, Fig. 8).

Coptocampylodon fontis (PATRULIUS, 1966)
(Pl. 2, Fig. 3pars)

This *incertae sedis* microfossil is very common in the Barremian–Aptian deposits of the Tethyan domain. The clarification of its taxonomy is beyond the scope of this paper. It would require a complex investigation that could clarify the status of the genus *Coptocampylodon* and the possible affiliation of the species *C. fontis* to this genus or to *Carpathoporella* DRAGASTAN 1967. The most recent papers diverge in their points of view on this subject (e.g. MASSE & ARNAUD VANNEAU, 1999; RADOIČIĆ, 2005). Remarks on the taxonomy and detailed synonymy of *Coptocampylodon* are given in SCHLAGINTWEIT et al. (2002). Beyond this aspect, it is notable that in the Pădurea Craiului area *C. fontis* is abundant in the Aptian-Albian allodapic limestones that are interbeds in the Vârciorog Formation.

The association identified in the Upper Aptian limestones of Pădurea Craiului includes two red algae: *Polystrata alba* (PFENDER) and *Parachaetetes asvapatii* PIA. *Polystrata alba* (Pl. 2, Fig. 4) is a peyssonneliacean alga occurring frequently in reef or para-reef deposits within the Hauterivian-Oligocene (?Miocene) time interval. Recent articles on this alga are by BASSI (1997) and AGUIRRE & BRAGA (1999). *Parachaetetes asvapatii* (Pl. 2, Fig. 7) is usually assigned to the solenoporaceans, and as a rule it has been found in Upper Cretaceous – Palaeocene deposits, but it was identified in Lower Cretaceous strata (GRANIER et al., 1991), and probably, also in the Upper Jurassic (BUCUR et al., 2005). Recent papers on *Parachaetetes asvapatii* were published by STOKAR (2000) and AGUIRRE & BARATTOLO (2001); the latter's article questioned the affiliation of this alga to the solenoporaceans. *Elianella elegans* PFENDER & BASSE 1948 has been considered by several authors as a recent synonym of *Parachaetetes asvapatii* (e.g. MOUSSAVIAN, 1989). Recently, BUČEK & KÖLER (2005), based on material from the Slovakian Palaeocene, reconsidered this synonymy, favouring the preservation of two separate species.

Finally, concerning the rivulariacean-type cyanobacteria (Pl. 2, Figs. 5–6) we can state only that they are present in some shallow subtidal or intertidal facies

Concerning the palaeoenvironment of the Upper Aptian algae in the Pădurea Craiului area, the dasycladalean algae have been found mainly in coarse-grained facies that include fragments of corals, rudists and gastropods. Only *Terquemella* sp. is present in facies representing low energy environments. However, *Polystrata alba* and *Parachaetetes asvapatii* occur in reef facies, the first as crusts associated with *Bacinella*, rudists or corals; the second is more common in environments dominated by corals.

4. CONCLUSION

The Upper Aptian carbonate deposits cropping out in the Subpiatră quarry area (Aleşd, Pădurea Craiului Mountains) most probably represent the carbonate platform from which the allodapic interbeds of the Vârciorog Formation were derived. We have identified in these deposits an association of calcareous algae dominated by dasycladaleans, and accompanied by red algae and rivulariacean-type cyanobacteria. Among the dasycladaleans, two species (*Terquemella* sp. and *Zittelina* sp.) are most probably new. Given the dramatic decline in both numbers and species of the calcareous algae (dasycladales in particular) in the vicinity of the Lower Aptian/Upper Aptian boundary (BUCUR, 1999), the dasycladalean association from the Upper Aptian of Pădurea Craiului described here acquires a special palaeontological and palaeogeographical significance.

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