

# Lower Cretaceous Halimedaceae and Gymnocodiaceae from Southern Carpathians and Apuseni Mountains (Romania) and the systematic position of the Gymnocodiaceae

## Unterkretazische Halimedaceae und Gymnocodiaceae aus den Südkarpaten und den Apuseni Bergen (Rumänien), sowie Diskussion der systematischen Stellung der Gymnocodiaceae

by

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### Contents

Abstract, Zusammenfassung .....	13
1. Introduction .....	13
2. Material and Methods .....	14
3. Results .....	14
4. Discussion .....	20
5. Conclusion .....	22
6. References .....	22

### Abstract

The paper presents a concise inventory of halimedacean and gymnocodiacean algae from the Resita–Moldova Noua zone (South Carpathians) and Padurea Craiului (Apuseni Mountains). A new genus and five new species are described: *Banatocodium surarui* n.gen. n.sp., *Halimeda fluegeli* n.sp., *Arabicodium aninensis* n.sp. (among halimedaceans); *Permocalculus ? halimedaformis* n.sp. and *Permocalculus minutus* n.sp. (among gymnocodiaceans). One of the new described species (*P. ? halimedaformis*) brings to attention the problem of the relationship between halimedaceans and gymnocodiaceans. We discuss the affiliation of *Gymnocodium* and *Permocalculus* to red algae, and conclude that Gymnocodiaceae should be considered rather green algae due to their general thallus structure.

### Zusammenfassung

Die Arbeit stellt eine kurze Bestandsaufnahme der Halimedaceen und Gymnocodiaceen der Resita-Moldova

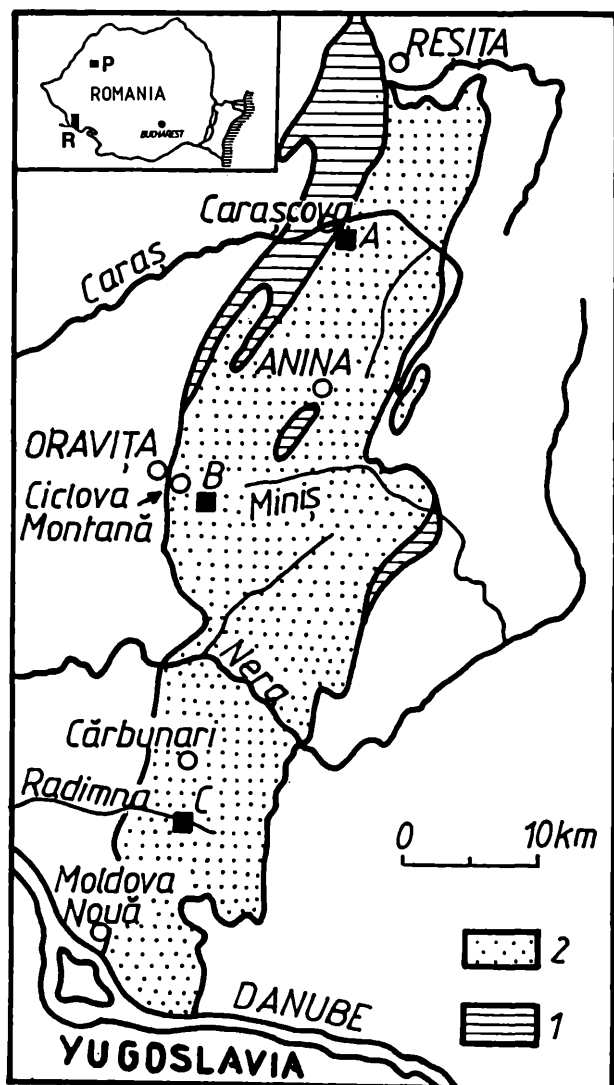
Noua Zone (Südkarpaten) und dem Padurea Craiului Massiv (Apuseni Gebirge) dar. Eine neue Gattung und 5 neue Arten werden beschrieben: Halimedaceae: *Banatocodium surarui* n.gen. n.sp., *Halimeda fluegeli* n.sp., *Arabicodium aninensis* n.sp.; Gymnocodiaceae: *Permocalculus ? halimedaformis* n.sp. und *Permocalculus minutus* n.sp. Eine neue Art (*P. ? halimedaformis*) macht das Problem der Beziehung zwischen Halimedaceen und Gymnocodiaceen deutlich. Die Zuordnung von *Gymnocodium* und *Permocalculus* zu den Rotalgen wird diskutiert, was dazu führt, daß die Gymnocodiaceen aufgrund ihrer generellen Thallusmerkmale eher zu den Grünalgen zu stellen sind.

### 1. Introduction

The Resita-Moldova Noua zone is situated within the south-western part of the southern Carpathians (Banat) (Fig. 1), representing the inner part of the sedimentary cover of the getic nappe in this area. The succession of Mesozoic deposits from this zone begins with Lower Liassic sediments and ends with Albian sediments, briefly interrupted during the Upper Clansayesian. During the Barremian and Aptian, shallow water carbonate sediments were deposited, containing a rich assemblage of foraminifers and calcareous algae. The halimedaceans and the gymnocodiaceans are abundant at certain levels, especially characterizing the external facies of the carbonate platform (BUCUR, 1991, 1994).

The calcareous massif of Padurea Craiului belongs to the Apuseni Mountains (Fig. 1) representing sedimentary autochthon from the Northern Apuseni. The Barremian-Aptian deposits are also developed here in a shallow carbonate facies where the algae represent an important

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**Figure 1:** The location of the studied areas on the map of Romania. P = Pădurea Craiului; R = Resita Zone. The location of the sampling sites containing the new described algae from the Resita – Moldova Noua area. 1 = Paleozoic deposits; 2 = Mesozoic deposits.

element of the micropaleontological assemblage (BUCUR, 1980–1981, 1988).

The study of the calcareous algae from the two areas demonstrated the existence of rich halimedacean and gymnocodiacean assemblages, mostly in the Resita-Moldova Noua zone (Fig. 1). Species of the genera *Arabicodium*, *Boueina* and *Halimeda* (from the Halimedaceae), *Palaeosiphonium* (probable Halimedaceae) as well as species of the genus *Permocalculus* (Gymnocodiaceae) are present. A new genus and three new species of Halimedaceae are described as well as two new species of Gymnocodiaceae.

The great morphological similarities between the two algal groups, and most of all their identical internal morphologies (medullar zone and cortical zone both consisting of undivided filaments) suggest their possible assignment to the same algal group. The existence of some reproductive organs inside the thallus of certain

species of *Codium* (Codiaceae) and even *Penicillus* (Halimedaceae) contradict the main argument (PIA, 1937; ELLIOTT, 1956) which supported the idea of assigning gymnocodiaceans to the red algae. Therefore a reexamination of the comparison with recent species of *Galaxaura* is thought necessary, as most of the evidence presented here suggests assigning gymnocodiaceans, together with halimedaceans and codiaceans, to the green algae.

The present paper has three main aims: (1) to provide an inventory of the Halimedaceae and Gymnocodiaceae from the south-west and west Romania, (2) to describe several new taxa, and (3) to discuss the systematic position of the Gymnocodiaceae.

## 2. Material and Methods

The algae studied in the present paper were identified in limestone samples collected from a great number of vertical profiles selected for the purpose of biostratigraphical investigation in the two areas. Several thousand thin sections have been produced, 300 of which contain algae belonging to the Halimedaceae and Gymnocodiaceae.

## 3. Results

An inventory of the main species of halimedaceans and gymnocodiaceans found in the two areas has already been made (BUCUR, 1980–1981, 1994). Consequently we shall review the main characteristics of the genera and of some species already identified, which is necessary for further comparisons of the two algal groups, as well as a detailed description of the new species.

### Family Halimedaceae LINK 1832

(syn. Udoteaceae (ENDLICHER) AGARDH, 1887–1888)

**Definition** (in BASSOULLET et al., 1983): Chlorophycean algae with thallus devoid of partitions, ramified or not, composed of more or less anastomosed filaments, differentiated in medullar and cortical zone.

### Genus *Arabicodium* ELLIOTT, 1957

**Diagnostic characters** (in ELLIOTT, 1957; BASSOULLET et al., 1983): Medullar and cortical filaments fine and more uniform. Cortical filaments widening at their terminations at the outer surface.

Species present in the Resita-Moldova Noua zone:

*Arabicodium aegagrapiloides* ELLIOTT, 1957  
(Pl. 2, Fig. 1)

*Arabicodium meridionalis* BUCUR, 1994  
(Pl. 2, Figs. 2, 5)

For details on the two species see BUCUR (1994).

*Arabicodium aninensis* n.sp.  
(Pl. 2, Figs. 3, 4, 6, 7)

**H o l o t y p e :** The specimen illustrated as Pl. 2, Fig. 3,

sample 396 Ghicin, thin section 396g (N.I. 5587), preserved in the author's collection at the department of Geology-Paleontology of the Babes-Bolyai University, Cluj-Napoca.

**Paratypes:** Specimens in Pl. 2, Fig. 6 (sample 396-Ghicin, thin section 396/4-N.I. 5563) and Pl. 2, Fig. 7 (sample 5-Mindrisag, thin section N.I. 5626) of the same collection.

**Derivatio nominis:** from Anina, a town situated in the neighbourhood of the locality where the samples were collected, which also gives the name to the Anina Mountains from the northern and central part of the Resita-Moldova Noua zone.

**Type locality:** The upper part of the Ghicin Valley, about 700 m from the confluence of the two little source creeks. About 3 km east of the locality Ciclova Montana (Fig. 1, B).

**Type level:** Upper Barremian–Lower Aptian, Valea Minisului Limestones bearing *Paracoskinolina hispanica* PEYBERNES. External infralittoral environment.

**Material** 13 specimens in thin section.

**Diagnosis** The calcareous skeleton of the thallus consists of cylindrical segments, with subparallel filaments in the medullar zone which is sometimes uncalcified (medullar hollow) (Pl. 2, Figs. 3, 7). The lateral zone is usually strongly calcified. The calcification partially obscures the thallus structure, therefore the filaments are difficult to observe in this part of the thallus (Pl. 2, Fig. 6). The proper cortical zone (outer cortex) marked by the terminal ramifications of the lateral filaments has a relatively low thickness (0.07–0.10 mm). In tangential section the cortical filaments have a polygonal outline.

Dimensions (mm):

L = 3.25 (maximum observed)

D = 1.24 –2.25

d = 0.38 –0.70

dtm = 0.023–0.055

dtl = 0.023–0.040

dte = 0.016–0.023 (enlarged distally to 0.030)

**Remarks:** 12 *Arabicodium* species are already known from Jurassic and Cretaceous deposits, and one from Tertiary sediments (Table 1). Among these, *Arabicodium indica* PAL, 1971, is an invalid species (= *nomen nudum*) as it has no holotype and the differentiation of its cortical filaments seems to exclude it from *Arabicodium* (BASSOULLET et al., 1983). *Arabicodium tibeticum* YU JING, 1976, is the only species of *Arabicodium* described from Tertiary deposits. According to BASSOULLET et al. (1983) this species is better assigned to the genus *Boueina*. However, in my opinion it could be assigned to the genus *Halimeda* if we consider the shape of the cortical filaments, though the quality of the original illustrations does not allow a proper estimation.

*Arabicodium aninensis* n.sp. differentiates from the other described *Arabicodium* species either by the thallus shape, or by the ratio between the dimensions of the medullar and cortical zones, or by the ratio between the filament

dimensions, the strong calcification of the lateral (subcortical) zone and the individualization of a relatively narrow cortex.

Genus *Boueina* TOULA, 1883

**Diagnostic characters** (in BASSOULLET et al., 1983): Medullar filaments, thicker than lateral and cortical ones, generally showing an irregular disposition; the branched cortical filaments become more and more slender.

Species present in the Resita-Moldova Noua zone:

*Boueina ? camenitzae* (DRAGASTAN & BUCUR, 1979)

(Pl. 1, Figs. 1, 2, 4)

Initially described as a species of the genus *Halimeda*, this alga has been tentatively reassigned to the genus *Boueina* (BUCUR, 1994). Uncertainty concerns mainly the existence of subcortical and cortical filaments with very large diameters as compared to those of the other cortical filaments.

*Boueina globosa* DRAGASTAN, BUCUR & DEMETER, 1978

(Pl. 1, Figs. 3, 6)

*Boueina hochstetteri* TOULA, 1883

(Pl. 1, Fig. 7)

For details of the three species see BUCUR (1994).

Genus *Halimeda* LAMOUREUX, 1812

**Diagnostic characters** (in BASSOULLET et al., 1983): Thallus articulated. Segments having parallel, thick, medullary filaments. Lateral filaments with constrictions and swellings (= utricles), ending in fine, short, cortical filaments.

A single species is present in the Lower Cretaceous deposits from the Resita-Moldova Noua zone:

*Halimeda fluegeli* n.sp.

(Pl. 3, Figs. 1–5)

**Holotype:** The specimen illustrated as Pl. 3, Fig. 1, sample 396-Ghicin, thin section 396j (N.I. 5590), preserved in the author's collection at the Department of Geology-Paleontology of the Babes-Bolyai University, Cluj-Napoca.

**Paratype:** The specimen illustrated as Pl. 3, Fig. 5, sample 396-Ghicin, thin section 396e (N.I. 5585), of the same collection.

**Derivatio nominis:** As a mark of appreciation for Prof. Dr. Erik Flügel, the director of the Institute of Paleontology in Erlangen, Germany, and for his work on calcareous algae, this species is dedicated to him.

**Type locality and Type level:** The same as for *Arabicodium aninensis* n.sp.

**Material:** 11 specimens in thin section.

**Diagnosis** Thallus consisting of cylindrical,

Species	L	D	d	e	dtm	dtc	Age
<i>A. aegagrapioides</i> ELLIOTT, 1957	3	0.8	0.4	–	–	–	L. Cr.
<i>A. bicasensis</i> DRAGASTAN, 1985	4.5	1.5	0.3	–	–	0.010–0.015	Js.– L. Cr.
<i>A. cantabricus</i> DRAGASTAN, 1982	3.0–3.3	1.2–1.5	1.0–1.4	–	–	0.006–0.003	L. Cr.
<i>A. elongatus</i> DRAGASTAN, 1971	3.5	1.2–1.5	–	–	–	0.015–0.03	Br
<i>A. hansii</i> DRAGASTAN, 1985	–	3.0–4.0	0.3–1.5	–	–	0.02–0.03	BrAp
<i>A. indica</i> PAL, 1971	0.96	0.3–0.36	–	0.22	0.078–0.096	0.007–0.024	Cr. sup.
<i>A. jurassicum</i> DRAGASTAN, 1971	6	1.5	0.6–1.2	–	–	0.030	Js. sup.
<i>A. meridionalis</i> BUCUR, 1994	3.59	1.0–2.5	0.45–1.1	–	0.04–0.05	0.010–0.020	Ap
<i>A. orientalis</i> DRAGASTAN, 1971	4.5–6.0	1.5–2.1	–	0.45–0.62	0.015	0.025–0.045	Br– Ap
<i>A. perforatus</i> DRAGASTAN, 1990	3.0–3.3	1.5–2.0	–	0.6	0.010	0.020	Js. sup.
<i>A. poignanti</i> GRANIER, 1986	5	1.4–1.8	0.4–0.6	0.5	–	0.030	Ber- rias
<i>A. texanus</i> JOHNSON, 1968	3.625	1.75–2.6	–	0.37–0.87	–	0.007–0.025	L. Cr.
<i>A. tibeticum</i> YU, 1976	2.77	1.09	0.65	0.22	–	0.025–0.033	PcEc
<i>A. aninensis</i> n.sp.	3.86	1.2–2.25	0.38–0.7	–	0.023–0.055	0.016–0.023	Br. sup.

**Table 1:** Comparative dimensional parameters of the *Arabicodium* species.

sometime waved segments (Pl. 3, Fig. 1). Medullary zone represents about  $\frac{1}{3}$  from the thallus diameter and is often uncalcified. When preserved, medullary filaments have a subparallel arrangement. Cortical filaments are perpendicular to the medullary zone and are dichotomically ramified. They are characterized by constrictions and swellings specific to this genus.

Dimensions (in mm):

L = 3.60 (maximum observed)

D = 0.62–0.64

d = 0.20–0.27

dtm = 0.030–0.055

dtc = 0.012–0.024 (frequent 0.016).

**Remarks:** Among the 11 fossil species of *Halimeda* already described (see table VI in BASSOULLET et al., 1983), only one was described from Lower Cretaceous deposits: *Halimeda camenitzae* DRAGASTAN & BUCUR, 1979. Considering the shape of the cortical filaments, devoid of constrictions and swellings characteristic to the genus *Halimeda*, this species has been recently and tentatively transferred to the genus *Boueina* (BUCUR,

1994). Also, only one Upper Cretaceous species is known: *Halimeda elliotti* CONARD & RIOULT, 1977. Quite recently, PONCET (1989) described *Halimeda soltanensis* from Upper Permian deposits, which considerably extends the stratigraphical range of the genus. The extremely long time interval between the Upper Permian and the Lower Cretaceous (about 130 my) from which no other representative of this genus is known raises the question of a possible case of homeomorphism. All the other 9 fossil species of *Halimeda* have been described from Tertiary deposits.

By its dimensions, *Halimeda fluegeli* n.sp. is close to *Halimeda nana* PIA, 1932, *Halimeda lingulata* YU JING, 1976, and *Halimeda entogensis* YU JING, 1976. It differs from *Halimeda nana* by a greater development of the cortical zone as compared to the medullary one, and a larger diameter of the medullary filaments. *Halimeda entogensis* is characterized by its small number of large medullary filaments, while the rough aspect of both medullary and cortical filaments differentiates *Halimeda lingulata* from *Halimeda fluegeli* n.sp.

*Halimeda* ? sp.  
(Pl. 3, Figs. 6, 7)

A single 6.35 mm long specimen of an alga with *Halimeda*-type structure has been found: parallel medullary filaments 0.03–0.04 mm in diameter, passing laterally in ovoidal utricles seemingly dichotomised, 0.06–0.08 mm in diameter. The outer cortex is very strongly micritized. It could correspond to some fine cortical filaments. The outer thallus diameter is of 0.62 mm while that of the medullary zone is of 0.23 mm. In a single place the lateral side of the thallus develops a hemispherical formation which might be interpreted either as an incipient vegetative branching or as a space for the reproductive organs (lower left side of the specimen figured in Pl. 3, Fig. 6).

Genus *Juraella* BERNIER, 1984

**Diagnostic characters** (in BERNIER, 1984): Thallus ramified. Medullary zone with fine, subparallel fascicles (= filaments) that curve to the exterior in the lateral and cortical zones. Some filaments are much enlarged in the medullar or cortical zone.

*Juraella bifurcata* BERNIER, 1984  
(Pl. 4, Figs. 5–8; Pl. 6, Fig. 7)

Many specimens belonging to this alga have been found within the Lower Cretaceous deposits from Padurea Craiului massif (BUCUR, 1988). This species was assigned by BERNIER (1984) to the Udoteaceae taking into account its general structure consisting of a medullar and a cortical zone. Enlarged filaments have been noticed although their significance has not previously been explained. However, these enlarged ramifications strikingly resemble the “reproductive organs” of some Gymnodiaceae. If we compare the specimens of *Juraella* from Pl. 4, Figs. 5–8 to those of *Permocalculus dragastani* (Pl. 7, Figs. 7, 8), their general structure resemblance is striking. Consequently, this alga could be included in the Gymnodiaceae rather than the Udoteaceae (= Halimedaceae). This problem is discussed further below.

? Halimedaceae

Genus *Palaeosiphonium* ELLIOTT, 1985

**Diagnostic characters:** Central, medullary zone showing a longitudinally directed tangle of tubular threads (= filaments). Subperipherally, they branch and anastomose without marked reduction in diameter. They branch externally in cortical filaments that cover in a spiral the entire body of the alga.

*Palaeosiphonium convolvens* (PRATURLON, 1984)  
(Pl. 4, Figs. 1–4)

After ELLIOTT (1985), “... the whole complex of filaments is enclosed by a single, subdermal, tubular thread which winds spirally from end to end of the body, without communicating throughout its main length with the inner complex”. However, the specimens of the Resita-Moldova Noua zone show clearly this communication between the

inner and outer filaments (Pl. 4, Figs. 1–4). The latter are practically ramifications of the first ones, covering the thallus in a densely, spiral succession.

The link between central and outer filaments is also mentioned by PRATURLON (1964) and is quite visible on the specimens he had illustrated (Figs. 30, 32, 33). Several ramifications of the medullary filaments can reach the same cortical spiral filament (Pl. 4, Figs. 2, 3, 4), while the medullary filament can also branch in two, three or four spiral cortical filaments (Pl. 4, Figs. 1, 2). The absence of a single cortical filament is demonstrated by the presence of some transversal walls marking its discontinuity, visible both on the specimens illustrated by PRATURLON (1964, Fig. 31 – mostly in its lower part, and Fig. 32 – in its upper part), and in the specimens of Pl. 4, Figs. 1 and 2 of the present paper. Taking into account all the above remarks a reconstruction of the thallus of *Palaeosiphonium convolvens* is shown in Figure 2.



**Figure 2:** Tentative reconstruction of the calcareous thallus of *Palaeosiphonium convolvens* (PRATURLON, 1964).

Dimensions (in mm):

L =	4.65 (maximum observed)
D =	0.29–1.11
d =	0.12–0.66
e =	0.078–0.16
dtm =	0.030–0.090
dte =	0.020–0.060

There is practically no morphologic or dimensional difference between the Lower Cretaceous specimens and those described from the Italian Upper Jurassic (PRATURLON, 1964) or the English Middle Jurassic (ELLIOTT, 1985). However, the greater number of specimens

identified within the Resita-Moldova Noua zone allowed slight revision of the range of dimensions.

Genus *Banatocodium* n. gen.

Type-species: *Banatocodium surarui* n. gen. n.sp. (Plate 5).

Diagnosis Calcareous skeleton with a large medullary hollow. Globular-ovoidal to cylindrical sub-medullary filaments giving rise to several thin sometimes bifurcated, cortical filaments.

Remarks Among fossil Halimedaceae (= Udoteaceae) *Banatocodium* n. gen. has, at first appearance, certain morphological resemblances with some species of the genus *Palaeoporella* STOLLEY, 1893 (e.g. *Palaeoporella recta* GNILOVSKAIA, 1972). However, the cortical filament distribution and branching, as well as characteristics of thallus structure (single medullary tube in *Palaeoporella*) clearly differentiate the two genera. Some similarities exist also to the genus *Pinatiporidium* (DRAGASTAN, 1990) from which the new genus differs both by the aspect of the medullary hollow and, mostly, by the structure of the cortex. The new genus differs from *Arabicodium* and *Boueina* by the filament shape and the filament ramification (see diagnostic characteristics of the two genera presented above).

*Banaticodium surarui* n.sp.

(Pl. 5, Figs. 1–7)

Holotype: The specimen illustrated in Pl. 5, Fig. 2, sample 2194-Carasova, thin section 2194/14 (N.I. 5631), preserved in the author's collection at the Department of Geology-Paleontology of the Babes-Bolyai University, Cluj-Napoca.

Paratype: The specimen illustrated as Pl. 5, Fig. 5, sample 2778-Carasova, thin section 2778/II-4 (N.I. 5632) from the same collection.

Derivatio nominis: Species dedicated to Prof. Nicolae Suraru, my teacher in Paleontology and Micropaleontology from the University of Cluj-Napoca. Type locality: South-southeast of Carasova village, on the slope bordering the road between the localities Resita and Anina, 500 m south from the bridge on the Caras River (Fig. 1 A).

Type level Lower Barremian, Valea Nerei Limestones bearing *Paracoskinolina ? jourdanensis* FOURY & MOULLADE, *Pfenderina globosa* FOURY, *Pseudolituonella gavonensis* FOURY, and *Protopenoplis ultragranulata* (GORBATCIK) (see location of sample and lithostratigraphic sequence in BUCUR, 1993b). Internal infralittoral environment.

Material: 20 specimens in thin section.

Diagnosis Cylindrical(?) calcareous thallus with uncalcified medullary zone (large medullary hollow). The calcified part includes the subcortical and cortical zone. On its inner side there are short submedullary filaments

(cylindrical or globular-ovoidal) (Pl. 5, Figs. 5, 7) with a bush of cortical filaments which may or may not branch towards the thallus outer surface. Within the calcareous wall there are sometimes ovoidal-spherical bodies, 0.10–0.15 mm in diameter which could be possible reproductive organs (Pl. 5, Figs. 2, 6).

Dimensions (in mm):

D = 3.72–5.58

d = 1.0–3.10

e = 0.93–1.70

dtl = 0.075–0.14

dte = 0.030–0.039

Remarks: It is quite difficult to determine a systematic assignment of this newly described alga. Many of its characteristics favour an assignment to the Halimedaceae (= Udoteaceae). The possible presence of some reproductive organs within the subcortical-cortical zone (Pl. 5, Figs. 2, 6) seems to contradict this assignment. However, such internal reproductive bodies have been discovered in recent halimedaceans and, as discussed below, there is a similar problem for other algae assigned to the Halimedaceae. A relationship to the Codiaceae, a family which is closely related to the Halimedaceae, is also suggested, although no modern Codiaceae resembles this new species.

Family Gymnocodiaceae ELLIOTT, 1955

Definition (in ELLIOTT, 1955): Extinct Rhodophyceae with thallus segmented or unsegmented, segments or units of varying size, form and degree of calcification, sporangia internal.

There is no mention of internal partitions in the original definition of the Gymnocodiaceae. The general thallus structure is identical with that in Udoteaceae (= Halimedaceae), i.e. medullar, lateral and cortical zones (see also ROUX & DELOFFRE, 1990). The only reason to assign them to Rhodophyta is the presence of internal reproductive organs in medullar, subcortical or cortical position, and the comparison with the red alga *Galaxaura*.

Genus *Permocalculus* ELLIOTT, 1955

Diagnostic characters (in ELLIOTT, 1955): Segments or units of variable form; spheroidal, ovoid or barrel-shaped segments, or elongate-irregular, finger-like or "waxing-and-waning" units. Calcification varying from very thin to massive or solid; pores small and cortical. Sporangia cortical or medullary. Segments or units usually larger, and pores finer, than those of *Gymnocodium*.

The following species were identified in the Lower Cretaceous deposits of the Resita-Moldova Noua zone.

*Permocalculus dragastani* BUCUR, 1985

(Pl. 7, Figs. 7, 8)

*Permocalculus ampullaceus* ELLIOTT, 1959

(Pl. 7, Fig. 6)

*Permocalculus* cf. *budaensis* JOHNSON, 1968

(Pl. 7, Fig. 9)

*Permocalculus (Pyrulites) deceneii* BUCUR, 1993  
(Pl. 7, Figs. 10, 11)

For details on the four species see BUCUR (1993a, 1994). Special mention should be made of *Permocalculus budaensis* JOHNSON. This species is a *nomen nudum* because JOHNSON (1968) did not indicate a holotype but a type-slide. All the specimens illustrated belong to this type-slide. Figs. 2, 3 and 4 of Pl. 1 of JOHNSON (1964) do not represent, in my opinion, species of *Permocalculus*. Probably they could be poorly preserved specimens of *Trinocladus tripolitanus* (RAINERI), a dasyclad alga. Fig. 5 of Pl. 1 is the only illustration that can be assigned to *Permocalculus*. It was figured by DELOFFRE (1992) as species holotype. It should more properly be regarded as a lectotype.

*Permocalculus ? halimedaformis* n.sp.  
(Pl. 6, Figs. 1–6)

**H o l o t y p e:** The specimen illustrated on Pl. 6, Fig. 2, sample 719-Radima, thin section 719/3 (N.I. 5628), preserved in the author's collection at the Department of Geology-Paleontology of the Babes-Bolyai University, Cluj-Napoca.

**P a r a t y p e s:** The specimens illustrated in Pl. 6, Fig. 3 (thin section 719/4, N.I. 5629) and Pl. 6, Fig. 6 (thin section 719/3, N.I. 5628) of the same collection.

**D e r i v a t i o n o m i n i s:** From its striking morpho-structural resemblance to species of the family Halimedaceae.

**T y p e l o c a l i t y:** Radimna Valley, at about 2200 m from its source, 5 km south of the Carbutari village (Fig. 1, C).

**T y p e l e v e l** Late Barremian–Lower Aptian, Valea Minisului Limestones bearing *Palaeodictyoconus arabicus* (HENSON) and *Palorbitolina lenticularis* (BLUMENBACH).

**M a t e r i a l:** 45 specimens in thin section.

**D i a g n o s i s:** Cylindrical calcareous skeleton with the outer surface marked by slight constrictions and swellings disposed at relatively equal distances. The well preserved filaments of the medullary zone are parallel-subparallel. They curve and branch gradually towards the outer side giving rise to cortical filaments. Their diameter gradually decreases from the subcortical zone outwardly, with a short terminal enlargement. Within the subcortical-cortical zone there are ovoidal-spheroidal, micritic bodies, possible reproductive organs.

Dimensions (in mm):

L =	3.35 (maximum observed)
D =	0.74–1.08 (frequent 0.87–0.94)
d =	0.38–0.62
dtm =	0.060–0.080
d <sub>tl</sub> =	0.032–0.047
d <sub>tc</sub> =	0.010–0.012
ds =	0.13–0.20/0.20–0.27

**R e m a r k s** The specimens sectioned longitudinally (e.g. Pl. 6, Fig. 2) show a slight moniliform contour, with a minimum diameter of 0.74–0.84 mm and a maximum diameter of 0.87–1.03 mm. There is no trace of transversal walls which could delimit cells within medullary or cortical filaments, having a configuration and a disposition identical to those of species of *Boueina*. The only element which supports the assignment of the specimens under discussion to Gymnocodiaceae is the presence of possible reproductive organs inside the thallus. In fact, they represent modified filaments originating within the filaments of the medullary or subcortical zone, and generating in turn, cortical filaments which open to the exterior (Pl. 6, Figs. 4, 6). However, this characteristic is present in specimens of *Juraella bifurcata* BERNIER, an alga assigned to Udoteaceae (= Halimedaceae) (Pl. 6, Fig. 7). *Permocalculus ? halimedaformis* n.sp. differentiate from *Permocalculus ampullaceus* ELLIOTT by less marked constrictions, by its smaller dimensions and the complete thallus calcification. Owing to its morphologic characteristics the new species differs essentially from all the other Cretaceous species of *Permocalculus* (Table 2).

*Permocalculus minutus* n.sp.  
(Pl. 7, Figs. 1–5)

**H o l o t y p e:** The specimen illustrated in Pl. 7, Fig. 1, sample 719-Radimna, thin section 719/5 (N.I. 5630) preserved in the author's collection from the Geology-Paleontology department, of the Babes-Bolyai University, Cluj-Napoca.

**P a r a t y p e s** Specimens illustrated in Pl. 7, Fig. 2 (same thin section as the holotype) and Pl. 7, Fig. 5 (thin section 719/3 (N.I. 5628)) of the same collection.

**D e r i v a t i o n o m i n i s:** From the small dimensions of the thallus.

**T y p e l o c a l i t y** and **t y p e l e v e l:** the same as *Permocalculus ? halimedaformis* n.sp.

**M a t e r i a l** 21 specimens in thin section.

**D i a g n o s i s:** Small sized *Permocalculus* species. The uncalcified medullary zone is represented by a space filled either by micritic sediment or by sparry calcite. Calcification affects only the cortical zone pierced by thin filaments, dichotomically branched. Their diameter gradually decreases from 0.028 to 0.008–0.010 mm, to enlarge again up to 0.020–0.024 mm outwardly. The external section of the filaments is round. Quite often the filaments are obliterated by the strong calcification. On the boundary between the medullary hollow and the cortical zone there are small oval bodies, probably representing reproductive organs (Pl. 7, Fig. 5). Sometimes they can also be observed within the cortical zone where they have smaller dimensions (Pl. 7, Fig. 2).

	L	D	dp	ds	Age
<i>P. ampullaceus</i> ELLIOTT, 1955	11	3	0.012	–	Vg–Hv
<i>P. budaensis</i> JOHNSON, 1968	0.97–0.65	0.4–0.8	0.021–0.030	0.054–0.140	Al–Cm
<i>P. dragastani</i> BUCUR, 1985	5	0.73–1.74	0.020–0.040	0.098–0.16	Be–Vg
<i>P. elliotti</i> JOHNSON & KASKA, 1965	0.92–2.62	0.82–1.09	0.014–0.018	0.051–0.088	Juras. sup. –Neocom.
<i>P. gavrovoensis</i> DELOFFRE, 1991	3.77	0.91–1.82	0.042	0.080–0.100	Maastricht
<i>P. geticus</i> DRAGASTAN, 1970	–	0.92–1.40	0.030–0.045	0.090	Br–Ap
<i>P. gosaviensis</i> SCHLAGINTWEIT, 1991	0.9	0.35–0.60	0.016–0.033	0.04–0.06	Coniac
<i>P. iagifuensis</i> SIMMONS & JOHNSTON, 1991	1.875–4.6	0.75–2.2	0.018–0.023	–	Miocene
<i>P. inopinatus</i> ELLIOTT, 1956	5	1.75	0.020	–	Br–Ap
<i>P. irenae</i> ELLIOTT, 1958	2–3	0.75–1.0	0.007–0.015	0.100–0.175	Al–Cm
<i>P. torinosensis</i> (ENDO, 1961)	7.2	0.86–1.89	0.027–0.041	–	Jur. sup.
<i>P. walnutensis</i> JOHNSON, 1968	2.075	0.9–2.595	0.015–0.025	0.029–0.035	Al–Cm
<i>P. (Pyrulites) deceneii</i> BUCUR, 1993	3.0	low. 0.25–0.75 up. 0.98–1.16	0.008–0.039	0.05–0.016	Br–Ap
<i>P. minutus</i> n.sp.	1.78	0.34–0.72	0.008–0.028	0.032–0.064	Ap
<i>P. ? halimedaformis</i> n.sp.	3.35	0.74–1.08	0.010–0.012	0.13–0.20	Ap

**Table 2:** Comparative dimensional parameters of the post-Paleozoic species of *Permocalculus*.

Dimensions (in mm):

L = 1.78 (maximum observed)

D = 0.34 –0.72 (frequent 0.38–0.59)

d = 0.20 –0.46 (frequent 0.21–0.34)

d<sub>tc</sub> = 0.008–0.028

ds = 0.032–0.064 (frequent 0.040–0.048)

**Remarks:** Owing to its small dimensions, *Permocalculus minutus* n.sp. differs from most Cretaceous species of this genus. Only *Permocalculus budaensis* JOHNSON, 1968, from Albian–Cenomanian, and *Permocalculus gosaviensis* SCHLAGINTWEIT, 1991, from Coniacian have comparable dimensions. The new species differs from *Permocalculus budaensis* by the smaller diameter of the filaments and the more reduced dimensions of the reproductive organs. The thallus shape and the smaller size of the cortical filaments also differentiate it from *Permocalculus gosaviensis*.

## 4. Discussion

### Previous studies

PIA (1937) assigned the Gymnocodiaceae to the Rhodophyta. The same author had previously assigned this algal group to the Codiaceae (= in fact Halimeda-ceae). In 1937 PIA wrote: "In mehreren Arbeiten (...) habe ich schon darauf hingewiesen, dass es im Perm Kalkalgen gibt, die man wegen der Gestalt ihrer Sporangien nur mit *Galaxaura* vergleichen kann (...) Solche Sporangien sind bei Codiaceen gänzlich unbekannt (...) Von Querwänden in den Zellfäden sieht man an den Fossilien nichts. Es scheint aber wohl, dass die Zellwände

selbst auch bei der rezenten *Galaxaura* nicht verkalkt sind (...) Im vegetativen Aufbau erinnern sie oft sehr an Codiaceen, besonders *Boueina* und *Halimeda*."

This comparison was repeated by ELLIOTT (1955) who underlines the resemblance between the calcification in *Galaxaura* and *Gymnocodium*, calcification affecting only the outer part of the cortex (though the specimen from Pl. 1, Fig. 3 (= *Gymnocodium belerophontis* (ROTHPLETZ, 1894) clearly shows the presence of some medullary subparallel calcified filaments). Subsequently, specimens of *Gymnocodium* or *Permocalculus* with the whole thallus calcified were figured by REZAK (1959) and GÜVENC (1966). From this point of view, the type of calcification cannot be an argument for the comparison of the two algal groups.

### The presence of reproductive organs

Previous workers (ELLIOTT, 1955; MU, 1991) stressed also the importance of the presence of the reproductive organs inside the thallus when considering the classification of the Gymnocodiaceae. However, it is already known that green algae from the family Codiaceae have reproductive organs inside the thallus (BORDEN & STEIN, 1969; BOLD & WYNNE, 1985). From a morphological point of view, the Codiaceae have basically the same structure as the Halimeda-ceae and the Gymnocodiaceae: siphons set vertically in the medullar area, and horizontally within the cortical area, the latter having also a photosynthetic role. As far as the genus *Codium* is concerned, while filaments get closer to the periphery,



their terminal part becomes a large utricle. The utricle shape is an important characteristic in classifying species. On the utricle margins reproductive structures appear inside the thallus (BOLD & WYNNE, 1985).

Moreover, reproductive organs inside the thallus have also been reported from some species of recent Halimedaceae (*Penicillus*) by HILLIS-COLINVEAUX (1984). KIRKLAND et al. (1993) described from the Pennsylvanian of New Mexico well-preserved specimens of *Eugonophyllum*, an alga assigned by KONISHI & WRAY (1961) to the Codiaceae. Considering the morphologic similarities between *Eugonophyllum*, *Halimeda* and *Udotea*, KIRKLAND et al. (1993) assign this alga to the Udoteaceae, however noting that: “ The only feature of *Eugonophyllum* that is not consistent with the family Udoteaceae are the oval, spar-filled chambers interpreted as reproductive structures ...”

#### Comparison Halimedaceae-Gymnocodiaceae

MU (1991) discusses the relationship between Halimedaceae (= Udoteaceae) and Gymnocodiaceae, starting from the analogies concerning the calcareous skeleton of the two algal groups. Finally the author decides to maintain the Gymnocodiaceae among the red algae, largely on the basis of the presence of the reproductive organs inside the thallus, similar to the recent genus *Galaxaura* from Chaetangiaceae. Considering the arguments already presented, I consider it as necessary to re-examine the Chaetangiaceae of the genus *Galaxaura*. The latter belongs to the Rhodophyceae (Nemalionales) which, according to IONESCU & TIPA (1977) are: algae, most of them marine, **pluricellular**, with a thallus consisting of uni- or multiaxial clads, often differing very much one from another. The cells are uni- or plurinucleate, connected by synapses through the pores existing between the ‘sister’ cells ...” *Galaxaura*, like all rhodophytes, is pluricellular, as ELLIOTT (1961) mentioned. The sections of SVEDELIUS (1913, in ELLIOTT, 1961) show that *Galaxaura glabriuscula* KJELLM consists of distinct cells. The fact that the calcified zone corresponds only to the outermost cell layer is not an argument in supporting the general impossibility of calcification for intercellular synapses. Only a complete thallus calcification could give an answer to this problem. However, such a calcification occurs in species of Gymnocodiaceae (both *Gymnocodium* and *Permocalculus*; see REZAK, 1959, pl. 71, fig. 12; GÜVENC, 1966, pl. 2, fig. 4 and the specimens of *Permocalculus ? halimedaformis* figured in the present paper, Pl. 6, Figs. 1–6). In none of these specimens the existence of a transversal wall on the filaments could be noticed, either medullar or cortical, to suggest a pluricellular structure.

SIMMONS & JOHNSTON (1991), described a new Miocene species, *Permocalculus iagifuensis* and suggest a link with the Recent genus *Galaxaura* of the Chaetangiaceae. But, the authors suggest also that there may be a good case to include the Gymnocodiaceae in the green algae.

KUSS (1994) describes ? *Permocalculus* sp. from the

Upper Cretaceous of Northern Africa, a species which according to the given illustration (Pl. 3, Figs. 6, 7) preserves by calcification both medullar and cortical filaments. As the author mentions: “ No cross partitions were found in both types of filaments” And further: “ The systematic assignment of the described specimens to the gymnocodiaceans is mainly supported by their sporangial cavities, a character which is most indicative for the red algal affinities (MU, 1991). However, the red algal nature of the gymnocodiaceans in general needs further confirmations, like the proof of cross partitions within the filaments, or septal plugs as mentioned by MU (1991). Nevertheless, the described specimens of ? *Permocalculus* draw features of the soft tissues which are rarely preserved in the fossil record ...” We have to notice that *Boueina pygmaea* PIA and ? *Permocalculus* sp. occur together, within the same thin section (KUSS, 1994, Pl. 3, figs. 5, 8–11). Thus, the morphologic similarities between Gymnocodiaceae and Halimedaceae-Codiaceae, already mentioned by PIA (1937) and emphasized by MU (1991, Fig. 1), are underlined once more. The presence of internal reproductive organs in the specimens of the latter green algal families makes the assignment of Gymnocodiaceae to the red algae questionable. In my opinion, the Gymnocodiaceae must be included among the green algae, together with the Codiaceae and Halimedaceae.

Another question can be raised concerning the role of reproductive organs played by the ovoidal-spheroidal chambers filled with micrite, characterizing the Gymnocodiaceae, as the presence of spores (cysts) inside chambers was not reported. The question is of much importance when we consider the fact that such micrite-filled voids are also present in some fossil specimens assigned to the Halimedaceae (= Udoteaceae). For instance, what could be the significance of the large micritic, subcortical or cortical voids of *Boueina ? camenitzae* (DRAGASTAN & BUCUR, 1979) (Pl. 1, figs. 1, 2, 4)? Could they be reproductive organs, or just modified utricles, generating usual cortical filaments? The same question may be asked in connection with the large (swelled) filaments of *Juraella bifurcata* BERNIER, 1984 (Pl. 4, figs. 5–8; Pl. 6, fig. 7). Such structures are also visible in some Paleozoic species of *Orthosiphon*, *Orthosiphonoides* and *Litanaia* (MU, 1991) as well as in the Mesozoic species *Arabicodium elongatus* (DRAGASTAN, 1971, pl. VII, figs. 3, 4, 7), *Arabicodium orientalis* (DRAGASTAN, 1971, pl. VIII, fig. 2; see also BAKALOVA, 1976, pl. 1, fig. 5), *Arabicodium texanus* (JOHNSON, 1968; all specimens in pl. 2) and even to *Halimeda elliotti* (CONARD & RIOULT, 1977, pl. 1, figs. 4, 5, 9, 10, 19 making somehow uncertain the author’s assertion that: “... Aucune différenciation anatomique susceptible d’indiquer la présence d’organes de reproduction n’ a été observé dans le thalle”). The same can be said about *Halimeda* sp., illustrated by KUSS & CONRAD (1991, Figs. 2–5), in which ovoidal micritic subcortical-cortical bodies can be noticed, as well as in the specimen figured by CHIRCEV & BAKALOVA

(1974, Pl. IV, fig. 2) under *Arabicodium aegagrapiloides*. Modified utricles (i.e. utricles much larger in diameter than those usually present in the subcortical-cortical zone in which they are included) occur even in the Upper Paleozoic and may generate problems in the systematic assignment of some specimens (compare, for instance, fig. 3 in Pl. 35 from HUBMANN, 1990 = *Litanaia graecensis* n.sp., to fig. 7 in Pl. 46 from OKLA, 1992 = *Succodium difficile* KORDE, 1965).

It is also significant to mention paleoecological information: the Halimedaceae and the Gymnocodiaceae occur constantly together characterizing (for example in the Resita-Moldova Noua zone) the external infralittoral paleoenvironment.

Discussing the relationship between Halimedaceae (= Udoteaceae) and Gymnocodiaceae, MU (1991:60) assume that: "... The erect group of fossil Udoteaceae resembles Gymnocodiaceae in many ways: growth form, vegetative structure, paleoecological and geographical distribution, etc." He also states that: "... in practice it is often difficult to distinguish between them" and, further considers that:

The major difference (...) which can be deciphered is that the gymnocodiaceans contain internal reproductive organs which are usually absent in the udoteaceans." In MU's (1991) opinion "... problems in determining the systematic position and classification of Gymnocodiaceae and fossil Udoteaceae are the result of inadequate information available regarding fossil material." In my opinion these problems are equally the consequence of inadequate knowledge concerning recent material, because, as noted above, recent researches revealed the presence of internal reproductive organs in the Halimedaceae as well.

## 5. Conclusion

17 species of Halimedaceae and Gymnocodiaceae (calcareous algae) have been described and illustrated from the Lower Cretaceous of Romania including a new genus and five new species.

Considering the similar vegetative structure of Halimedaceae and Gymnocodiaceae, the presence of reproductive organs inside the thallus of green algae of the families Codiaceae and Halimedaceae, and the absence of vertical partitions delimiting distinct cells inside the filaments of Gymnocodiaceae, I consider that the Gymnocodiaceae should be assigned to green algae rather than to red algae.

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## 6. References

- BAKALOVA, D., 1976. Algues calcaires des textures organogènes de la formation de Balgarene (groupe urgonien de Lovetch). (Bulgare, résumé français) — Bulg. Acad. Sci., Paléont., Stratigr., Litol., 5:3–12, 1 pl., Sofia.
- BASSOULLET, J.-P., BERNIER, P., DELOFFRE, R., GÉNOT, P., PONCET, J. & ROUX, A., 1983. Les algues Udoteacées du Paléozoïque au Cénozoïque. — Bull. Centres Rech. Explor.-Prod. Elf-Aquitaine, 7/2:449–621, 13 figs., 16 tpls., 16 pls., Pau.
- BERNIER, P., 1984. Les formations carbonatées du Kimmeridgien et du Portlandien dans le Jura méridional. Stratigraphie, micropaléontologie, sédimentologie. — Docum. Lab. Géol. Lyon, 92/2: 803 pp., 218 figs., 21 tpls., 36 pls., Lyon.
- BOLD, C.H. & WYNNE, M.J., 1985. Introduction to the algae. Structure and reproduction. — 720 p., New Jersey (Prentice Hall).
- BORDEN, C.A & STEIN, J.R., 1969. Reproduction and early development in *Codium fragile* (Suringar) Hariot: Chlorophyceae. — Phycologia, 8/2:91–99, 15 figs.
- BUCUR, I.I., 1980–1981. Algues calcaires du Crétacé inférieur des Monts Padurea Craiului. — Nymphaea, Foliae nat. Bihariae, VIII–IX:53–68, 6 pls., Oradea.
- BUCUR, I.I., 1985. *Permocalculus dragastani* sp. nov. (Algues Rhodophycées, Gymnodiacées) dans les dépôts du Crétacé inférieur de la zone de Resita-Moldova Noua (Banat, Roumanie). — Revue Paléobiologie, 4/2:203–209, 2 figs., 3 pls., Genève.
- BUCUR, I.I., 1988. Sur la présence de *Juraella bifurcata* (algues calcaires, Udoteacées) dans les dépôts du Crétacé inférieur des Monts Padurea Craiului. — Studia Univ. Babeş-Bolyai, Geol.-Geogr., XXXIII/1:47–50, 2 pls., Cluj-Napoca.
- BUCUR, I.I., 1991. Studiul Jurasicului si Cretacicului din unele perimetre cu perspectiva pentru carbunii liasici, intre Valea Minisului si Valea Nerei (Compartimentul central al zonei Resita, Banat). — Unpublished Ph. D. Thesis, 220 p., 51 figs., 12 tpls., 100 pls., Cluj-Napoca.
- BUCUR, I.I., 1993a. Some new or poorly known calcareous algae (Dasycladales, Gymnocodiaceae) in the Lower Cretaceous deposits from the Resita-Moldova Noua zone (Southern Carpathians, Romania). — Revista Espanola de Micropaleontologia, XXV/1:93–126, 3 figs., 2 tpls., 9 pls., Madrid.
- BUCUR, I.I., 1993b. Les représentants du genre *Protopenoplis* Weynschenk dans les dépôts du Crétacé inférieur de la zone de Resita-Moldova Noua (Carpathes méridionales, Roumanie). — Revue Micropaléontologie, 36/3:213–223, 3 figs., 2 pls., Paris.
- BUCUR, I.I., 1994. Algues calcaires de la zone de Resita-Moldova Noua (Carpathes méridionales, Roumanie). — Revue Paléobiologie, 13/1:147–209, 4 figs., 22 pls., Genève.
- CHRISCHEV, C. & BAKALOVA, D., 1974. Distribution of the algae in the Emen Limestone Formation (the Lovech Urganian Group). (in Bulgarian with English summary). — Bulg. Acad. Sci., Bull. Geol. Inst., Strat.-

- Litol., **XXIII**:65–78, 5 pls., Sofia.
- CONARD, M. & RIOULT, M., 1977. *Halimeda ellioti* nov. sp., algue calcaire (Chlorophyceae) du Turonien des Alpes Maritimes (SE France). — *Géologie Méditerranéenne*, **IV**/2:83–98, 3 figs., 3 pls., Marseille.
- DELOFFRE, R., 1992. Révision des Gymnodiaceae (algues rouges, Permien-Miocène). Taxonomie, biostratigraphie, paléobiogéographie. 3<sup>e</sup> partie. — *Revue Micropaléontologie*, **35**/1:23–37, 1 fig., 1 tbl., 2 pls., Paris.
- DRAGASTAN, O., 1970. New species of Dasycladaceae (calcareous algae) in the Lower Cretaceous of the Eastern Carpathians (Rumania). — *Rev. Paleobot. Palinol.*, **10**:117–129, 3 figs., 3 tpls., 2 pls., Amsterdam.
- DRAGASTAN, O., 1971. New algae in the Upper Jurassic and Lower Cretaceous in the Bicaz Valley, East Carpathians (Romania). — *Revista Espanola de Micropaleontologia*, **III**/2:155–192., 3 figs., 12 pls., Madrid.
- DRAGASTAN, O., 1982. Lower Cretaceous marine Algae and Calpionellidae from Caudas (San Pedro), Asturias Province (Spain). — *Cuadernos Geologia Iberica*, **8**:125–143, 1 fig., 4 pls., Madrid.
- DRAGASTAN, O., 1990. New Udoteaceae algae of the Mesozoic. — *Revista Espanola de Micropaleontologia*, **XXII**/3:481–498, 7 pls., Madrid.
- ELLIOTT, G.F., 1955. The Permian alga *Gymnocodium*. — *Micropaleontology*, **1**/1:83–90, 3 pls., New York.
- ELLIOTT, G.F., 1956. *Galaxaura* (calcareous algae) and similar fossil genera. — *Journ. Washington Acad. Sci.*, **46**/11:341–343, 1 fig., Washington.
- ELLIOTT, G.F., 1957. New calcareous algae from the Arabian Peninsula. — *Micropaleontology*, **3**/3:227–230, 1 pl., New York.
- ELLIOTT, G.F., 1958. Algal debris-facies in the Cretaceous of the Middle East. — *Palaeontology*, **1**/3:254–259, 1 fig., 4 pls. (45–48), London.
- ELLIOTT, G.F., 1959. New calcareous algae from the Cretaceous of Iraq. — *Revue Micropaléontologie*, **1**/4:217–222, 2 pls., Paris.
- ELLIOTT, G.F., 1961. The sexual organisation of Cretaceous Permocalculus (calcareous algae). — *Palaeontology*, **4**/1:82–84, 1 pl. (11), London.
- ELLIOTT, G.F., 1965. The interrelationships of some Cretaceous Codiaceae (calcareous algae). — *Palaeontology*, **8**/2:199–203, 2 pls. (23–24), London.
- ELLIOTT, G.F., 1985. *Palaeosiphonium*, a problematic Jurassic alga. — *Bull. Br. Mus. nat. Hist. (Geol.)*, **38**/5:283–286, 4 figs., London.
- GÜVENC, T., 1966. Description de quelques espèces d'algues calcaires (Gymnodiacees et Dasycladacees) du Carbonifère et du Permien des Taurus occidentaux (Turquie). — *Revue micropaléontologie*, **9**/2:94–103, 3 tpls., 3 pls., Paris.
- GRANIER, B., 1988. Algues Chlorophyceae du Jurassique terminal et du Crétacé inférieur en Alicante. — *Mediterranea, Ser. Geol.*, **5**(1966):5–95, 12 figs., 4 tpls., 12 pls., Alicante.
- HILLIS-COLINVAUX, L., 1984. Systematics of the Siphonales. — [in:] IRVING, D.E.G. & JOHN, D.M. (eds.). *Systematics of the Green Algae*. — 271–296, New York (Acad. Press).
- HUBMANN, B., 1990. Udoteaceen (Grünalgen) aus dem Grazer Paläozoikum (Österreich, Barradeikalke, Eifelium). — *Facies*, **22**:147–158, 7 figs., 1 tbl., 1 pl. (35), Erlangen.
- IONESCU, A.L. & TIPĂ, L., 1977. Rhodophyta – Clasificare. Caracterele ordinelor si principalelor familii si genuri. — [in:] PETERFI, S.T. & IONESCU, A.L. (eds.). *Tratat de algologie, II* (Rhodophyta, Phaeophyta). — 48–144, Bucuresti (Ed. Acad. RSR).
- JOHNSON, J.H., 1968. Lower Cretaceous Algae from Texas. — *Prof. Contrib. Colorado School Mines*, **4**:1–71, 16 tpls., 12 pls., Golden.
- KIRKLAND, B.L., MOORE, C.H. Jr. & DICKSON, J.A.D., 1993. Well preserved, aragonitic phylloid algae (*Eugonophyllum*, Udoteaceae) from the Pennsylvanian Holder Formation, Sacramento Mountains, New Mexico. — *Palaios*, **8**:111–120, 12 figs., Tulsa.
- KONISHI, K. & WRAY, J.L., 1961. *Eugonophyllum*, a new Pennsylvanian and Permian algal genus. — *Journal Paleontology*, **35**:659–666, Washington.
- KUSS, J., 1994. Cretaceous (Albian-Turonian) calcareous algae from Egypt and Jordan – Systematics, stratigraphy and paleogeography. — *Abh. Geol. B.-A.*, **50**:295–317, Wien.
- KUSS, J. & CONRAD, M.A., 1991. Calcareous algae from Cretaceous carbonates of Egypt, Sinai, and southern Jordan. — *Journal Paleontology*, **65**/5:869–882, 6 figs., 4 pls., Washington.
- MU, X., 1981. Upper Permian calcareous algae from western Guizhang. (in Chinese with English summary). — *Acta palaeontologica Sinica*, **20**/1:31–49, 1 fig., 3 tpls., 4 pls., Nanjing.
- MU, X., 1991. Fossil Udoteaceae and Gymnodiaceae. — [in:] RIDING, R. (ed.). *Calcareous algae and stromatolites*, 146–166, 3 figs., 1 pl., Berlin –Heidelberg – New York (Springer-Verlag).
- OKLA, S.M., 1992. Permian algae and algal microfacies from Unayzah Quassim district, Saudi Arabia. — *Facies*, **27**:217–224, 2 figs., 1 tbl., 2 pls. (45–46), Erlangen.
- PIA, J., 1937. Di wichtigsten Kalkalgen des Jungpaläozoikums und ihre geologische Bedeutung. — *Congr. Strat. Carb. Heerlen*, **CR2**:765–856, 2 figs., 13 pls. (85–97), Heerlen.
- PONCET, J., 1989. Présence du genre *Halimeda* Lamouroux, 1812 (algue verte calcaire) dans le Permien supérieur du sud Tunisien. — *Revue Micropaléontologie*, **32**/1:40–44, 2 figs., 1 pl., Paris.
- PRATURLON, A., 1964. Calcareous algae from Jurassic-Cretaceous limestones of central Apennines (Southern Latium-Abruzzi). — *Geologica Romana*, **III**:171–202, 34 figs., Roma.
- REZAK, R., 1959. Permian algae from Saudi Arabia. — *Journal Paleontology*, **33**/4:531–539, 1 fig., 2 tpls., 2 pls. (71–72), Washington.
- ROUX, A. & DELOFFRE, R., 1990. Révision des Gymnodiaceae (algues rouges, Permien-Crétacé).

- Taxonomie, biostratigraphie, paléobiogéographie. 1<sup>re</sup> partie: Généralités sur la famille. — *Revue Micropaléontologie*, **32/2**:123–137, 2 figs., 2 tbls., Paris.
- SCHLAGINTWEIT, F., 1991. On the occurrence of the genus *Permocalculus* Elliott, 1955 (calcareous algae, Gymnodiaceae) in the Upper Cretaceous of the Northern Calcareous Alps (Branderfleck Formation, Gosau Formation) with the description of *Permocalculus gosaviensis* n.sp. — *Revue Paléobiologie*, **10/1**:37–46, 2 figs., 2 pls., Genève.
- SIMMONS, M.D. & JOHNSTON, M.J., 1991. *Permocalculus iagifuensis* sp. nov.: a new Miocene gymnodiacean alga from Papua New Guinea. — *J. Micro-paleontol.*, **9/2**:238–244, London.
- YU-JING, W., 1976. Calcareous algae from the Late Cretaceous and Palaeogene sediments in the Mount Jolmo Lugma region. — [in:] A report of scientific expedition in the Mount Jolmo Lugma region (1966–1968). (in Chinese). — *Academia sinica*, **2**:425–457, 12 figs., 12 pls., Peking (Science Press).

## PLATE 1

Figs. 1, 2, 4. *Boueina ? camenitzae* (DRAGASTAN & BUCUR, 1979).

Fig. 1. Transverse section. Sample 2 bis I – Camenita; x 47.

Fig. 2. Longitudinal-oblique section. Sample 1241 – Doman; x 45.

Fig. 4. Oblique section. Sample 48b – Camenita; x 30.

Figs. 3, 6. *Boueina globosa* DRAGASTAN, BUCUR & DEMETER, 1978.

Fig. 3. Longitudinal-oblique section. Sample 59b – Foraj Sopot; x 47.

Fig. 6. Oblique section. Sample 2042 – Ogasul Gauril; x 68.

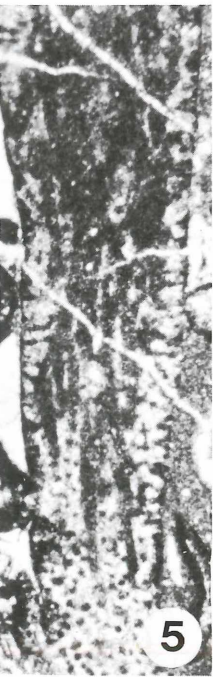
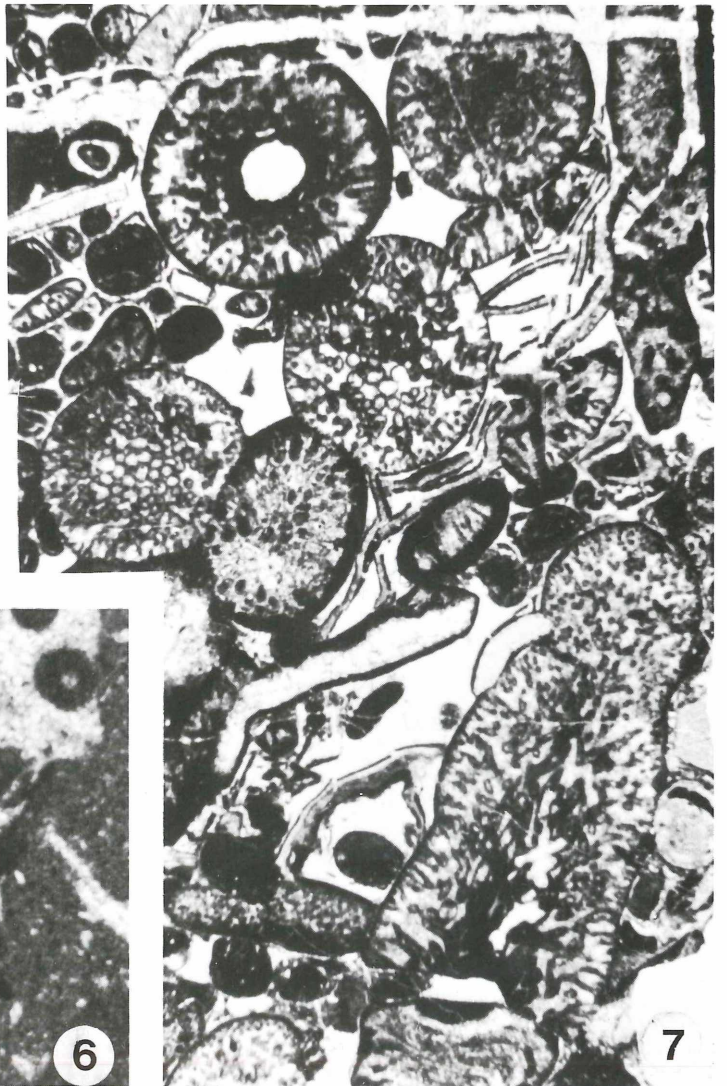
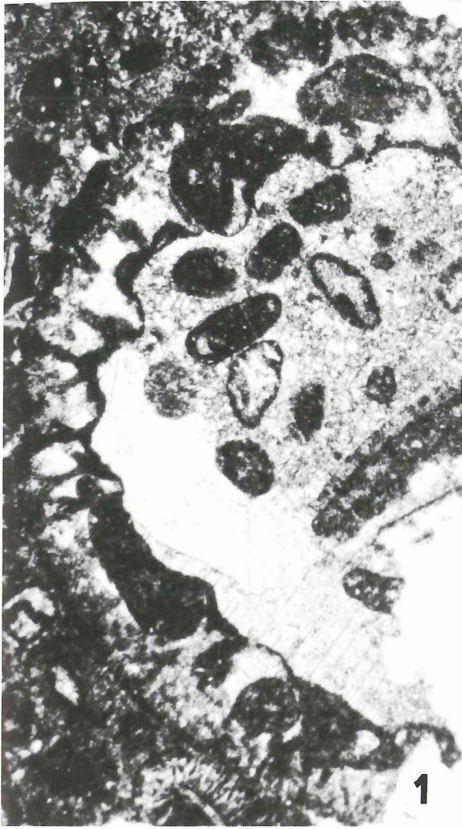
Fig. 5. *Boueina ? cf. Boueina ? camenitzae* (DRAGASTAN & BUCUR, 1979). Tangential-longitudinal section. Sample 48 – Camenita; x 37.

Fig. 7. *Boeina hochstetteri* TOULA, 1883. Longitudinal-oblique and transverse sections. Sample 19/2 – Valea Radimnei; x 16.

All samples from the Resita-Moldova Noua zone.

Figs. 1, 2, 4–7. Upper Barremian – Lower Aptian. Fig. 3: Upper Aptian.

PLATE 1



## PLATE 2

Fig. 1. *Arabicodium aegagrapiloides* ELLIOTT, 1957. Longitudinal section. Sample 57 – Camenita; x 50.

Figs. 2, 5. *Arabicodium meridionalis* BUCUR, 1994. Longitudinal sections.

Fig. 2. Holotype. Sample 36E – Doman; x 33.

Fig. 5. Sample 719/3 – Valea Radimnei; x 40.

Figs. 3, 4, 6, 7. *Arabicodium aninensis* n.sp.

Fig. 3. Longitudinal section. Holotype. Sample 396g – Ghicin; x 38.

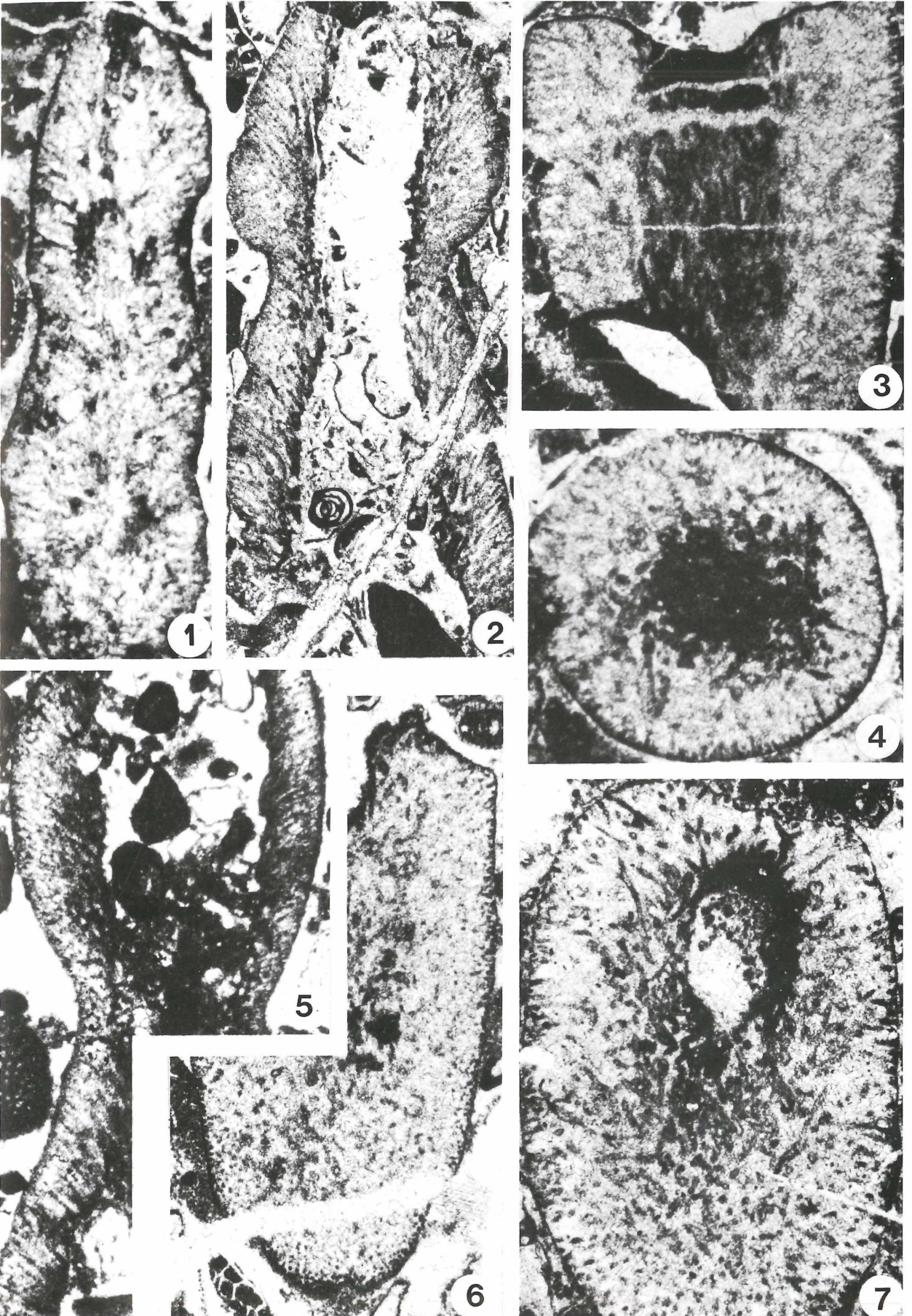
Fig. 4. Transverse section. Sample 396/18 – Ghicin; x 38.

Fig. 6. Oblique section. Paratype. Sample 396/4 – Ghicin; x 32.

Fig. 7. Oblique section. Paratype. Sample 5 – Mindrisag; x 30.

All samples from the Resita-Moldova Noua zone. Upper Barremian – Lower Aptian.

PLATE 2



### PLATE 3

Figs. 1–5. *Halimeda fluegeli* n.sp.

Fig. 1. Longitudinal section. Holotype. Sample 396j – Ghicin; x 50.

Fig. 2. Enlarged photo of the specimen in Fig. 1, showing the characteristic shape of the lateral and cortical filaments; x 100.

Fig. 3. Longitudinal section. Sample 397/14 – Ghicin; x 45.

Fig. 4. Longitudinal-oblique section. Sample 396e; x 75.

Fig. 5. Longitudinal-oblique section. Paratype. Sample 396e; x 75.

Figs. 6–7. *Halimeda* ? sp.

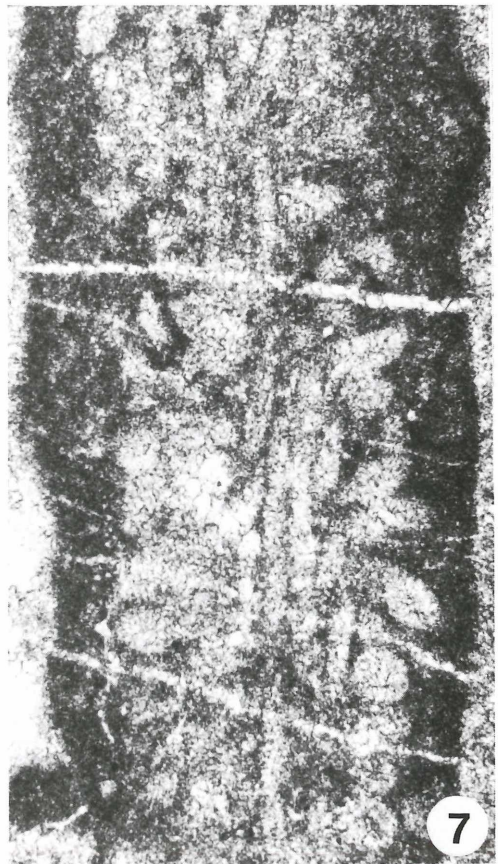
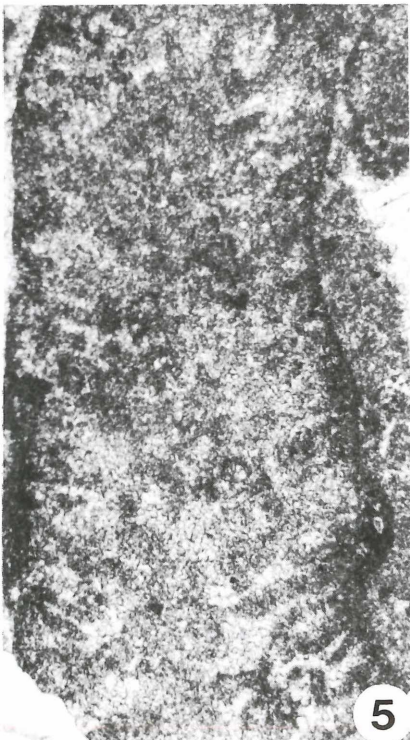
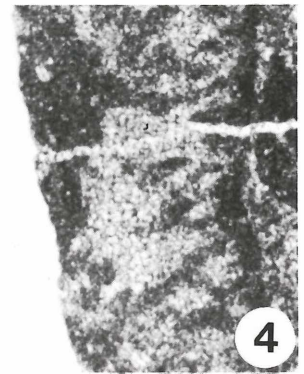
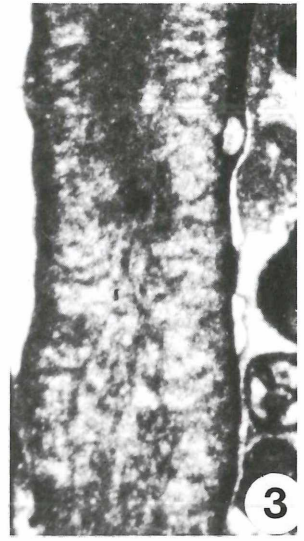
Fig. 6. Longitudinal section. Sample 1242 – Doman; x 50.

Fig. 7. Enlarged photo of the specimen in Fig. 6; x 100.

All samples from the Resita-Moldova Noua zone. Upper Barremian – Lower Aptian.



PLATE 3



#### PLATE 4

Figs. 1–4. *Palaeosiphonium convolvens* (PRATURLON, 1964).

Fig. 1. Longitudinal section. Sample 320, 5/4 – Foraj 1, Padina matei; x 40.

Fig. 2. Oblique section. Sample 319, 7/14 – Foraj 1, Padina Matei; x 53.

Fig. 3. Transverse section. Sample 319, 7/12 – Foraj 1, Padina Matei; x 75.

Fig. 4. Transverse-oblique section. Sample 319, 7/3 – Foraj 1, Padina Matei; x 55.

Figs. 5–8. *Juraella bifurcata* BERNIER, 1984.

Fig. 5. Transverse section. Sample 291B – Aconi, Cornet; x 52.

Fig. 6. Transverse section. Sample 171B – Valea Nerei; x 73.

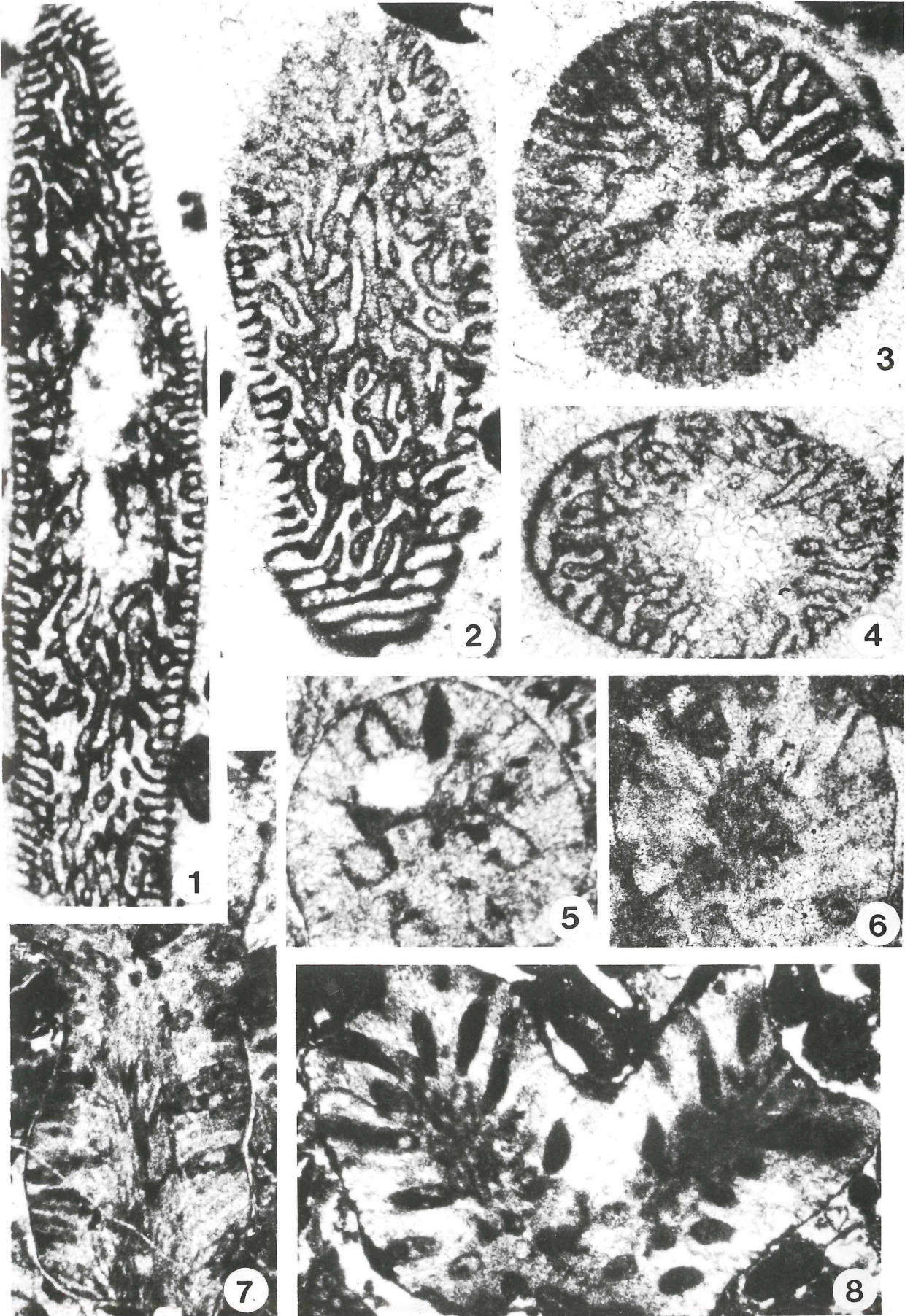
Fig. 7. Longitudinal section. Sample 174d – Virciorog; x 36.

Fig. 8. Longitudinal section. Sample 172 – Valea Radimnei; x 45.

Figs. 1–4, 6, 8. Samples from the Resita – Moldova Noua zone;

Figs. 5, 7. Samples from Padurea Craiului Massif. 1–5, 7. Lower Barremian; 6, 8. Upper Barremian – Lower Aptian.

PLATE 4



**PLATE 5**

Figs. 1–7. *Banatocodium surarui* n.gen. n.sp.

Fig. 1. General view of a sample containing several specimens in oblique or transverse-section. Sample 2194/14 – Carasova; x 4,5.

Fig. 2. Transverse–oblique section. Holotype. Sample 2194/14 – Carasova; x 8,5.

Fig. 3. General view of another sample containing several specimens. Sample 2778/II–4 – Carasova; x 8,5.

Fig. 4. Oblique section. Sample 2194/14 – Carasova; x 8,5.

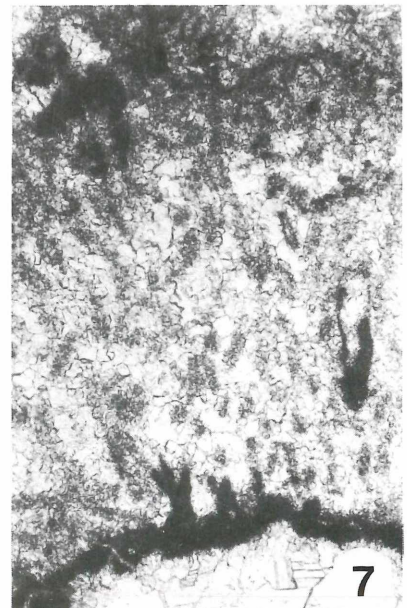
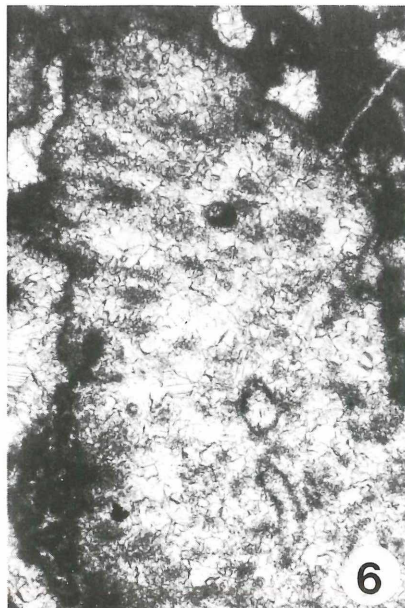
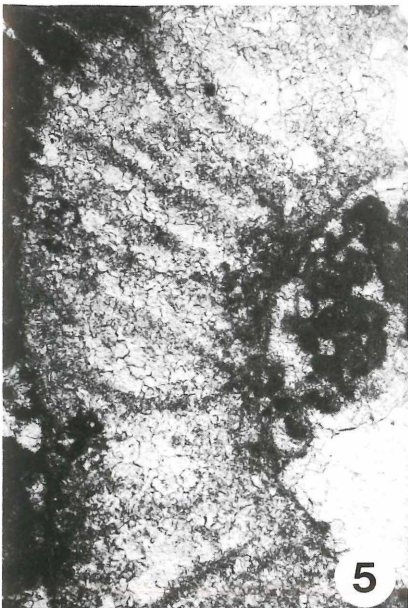
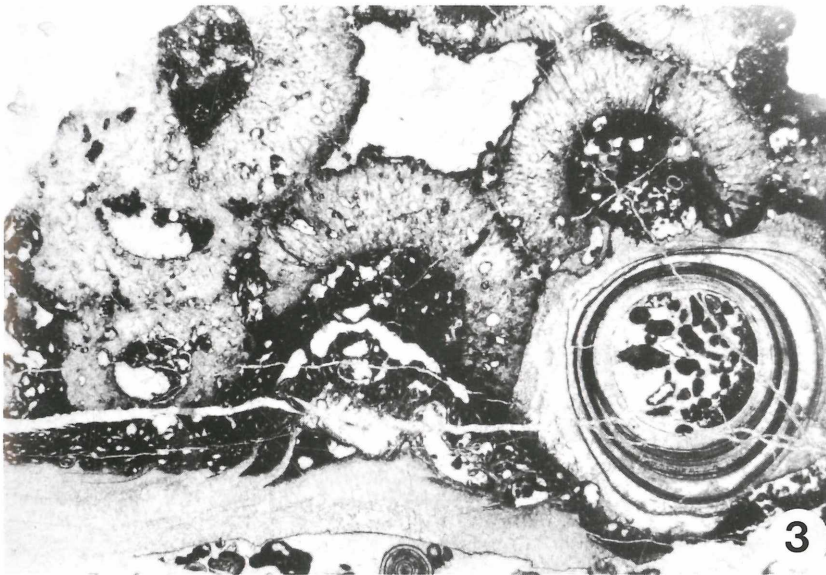
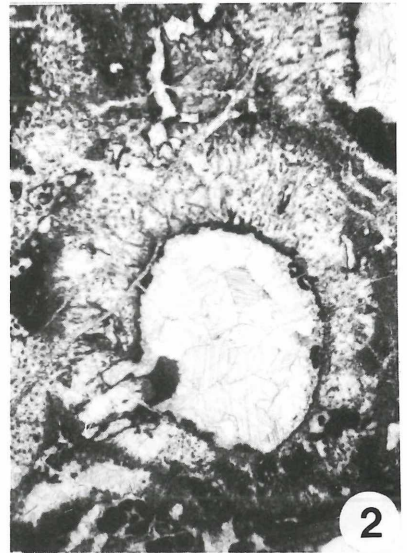
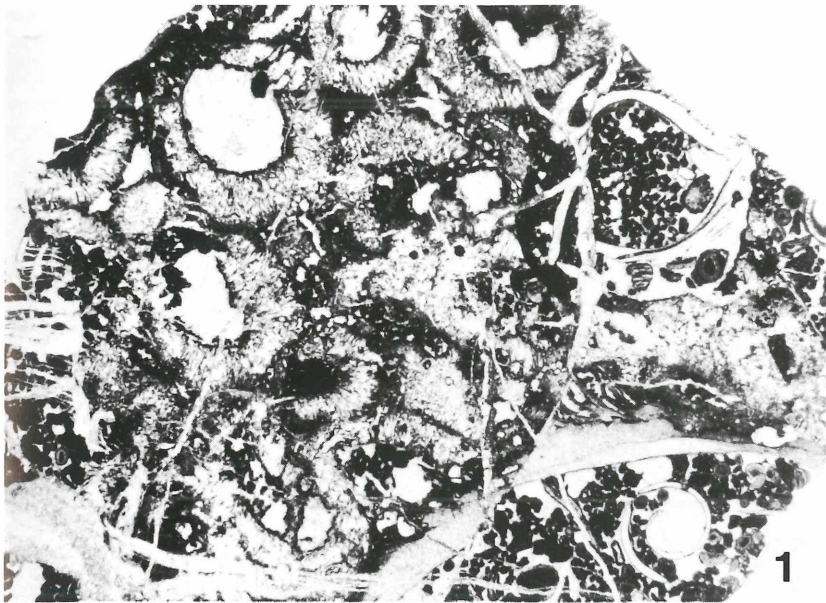
Fig. 5. Transverse-oblique section. Paratype. Sample 2178/II–4 – Carasova; x 40.

Fig. 6. Oblique section. Sample 2194/14 – Carasova; x 40.

Fig. 7. Enlarged photo of Fig. 2 (Holotype), showing the shape of the submedullary and cortically filaments.

Note in Figs. 5–7 the filament configuration. All samples from Resita – Moldova Noua zone. Lower Barremian.

PLATE 5



**PLATE 6**

Figs. 1–6. *Permocalculus ? halimedaformis* n.sp.

Fig. 1. Longitudinal-oblique section. Sample 719/5 – Valea Radimnei; x 45.

Fig. 2. Longitudinal section. Holotype. Sample 719/3 – Valea Radimnei; x 55.

Fig. 3. Longitudinal section. Paratype. Sample 719/4 – Valea Radimnei; x 63.

Fig. 4. Transverse-oblique section. Sample 719/5 – Valea Radimnei; x 70.

Fig. 5. Longitudinal-oblique section. Sample 719/2 – Valea Radimnei; x 63.

Fig. 6. Oblique section. Sample 719/3 – Valea Radimnei; x 63.

Fig. 7. *Juraella bifurcata* BERNIER, 1984. Oblique section. Sample 174 c – Vârciorog; x 87.

Figs. 1–6. Samples from Resita – Moldova Noua zone. Lower Aptian.

Fig. 7. Sample from Padurea Craiului Massif. Lower Barremian.

PLATE 6



## PLATE 7

Figs. 1–5. *Permocalculus minutus* n.sp.

Fig. 1. Longitudinal section. Holotype. Sample 719/5 –Valea Radimnei; x 70.

Fig. 2. Longitudinal section. Sample 719/5 –Valea Radimnei; x 70.

Fig. 3. Oblique section. Paratype. Sample 719/4 –Valea Radimnei; x 70.

Fig. 4. Transverse-oblique section. Sample 719/5 –Valea Radimnei; x 90.

Fig. 5. Transverse-oblique section. Sample 719/3 –Valea Radimnei; x 90.

Fig. 6. *Permocalculus ampullaceus* ELLIOTT, 1954. Longitudinal oblique section. Sample 63 – Foraj Sopot; x 20.

Figs. 7, 8. *Permocalculus dragastani* BUCUR, 1985.

Fig. 7. Longitudinal section. Holotype. Sample 1186/1c – Ilidia; x 55.

Fig. 8. Longitudinal-oblique section. Sample 396/9 – Ghicin; x 16.

Fig. 9. *Permocalculus budaensis* JOHNSON, 1968. Sample 15 – Valea Nerei; x 20.

Figs. 10–11. *Permocalculus (Pyrulites) deceneii* BUCUR, 1993.

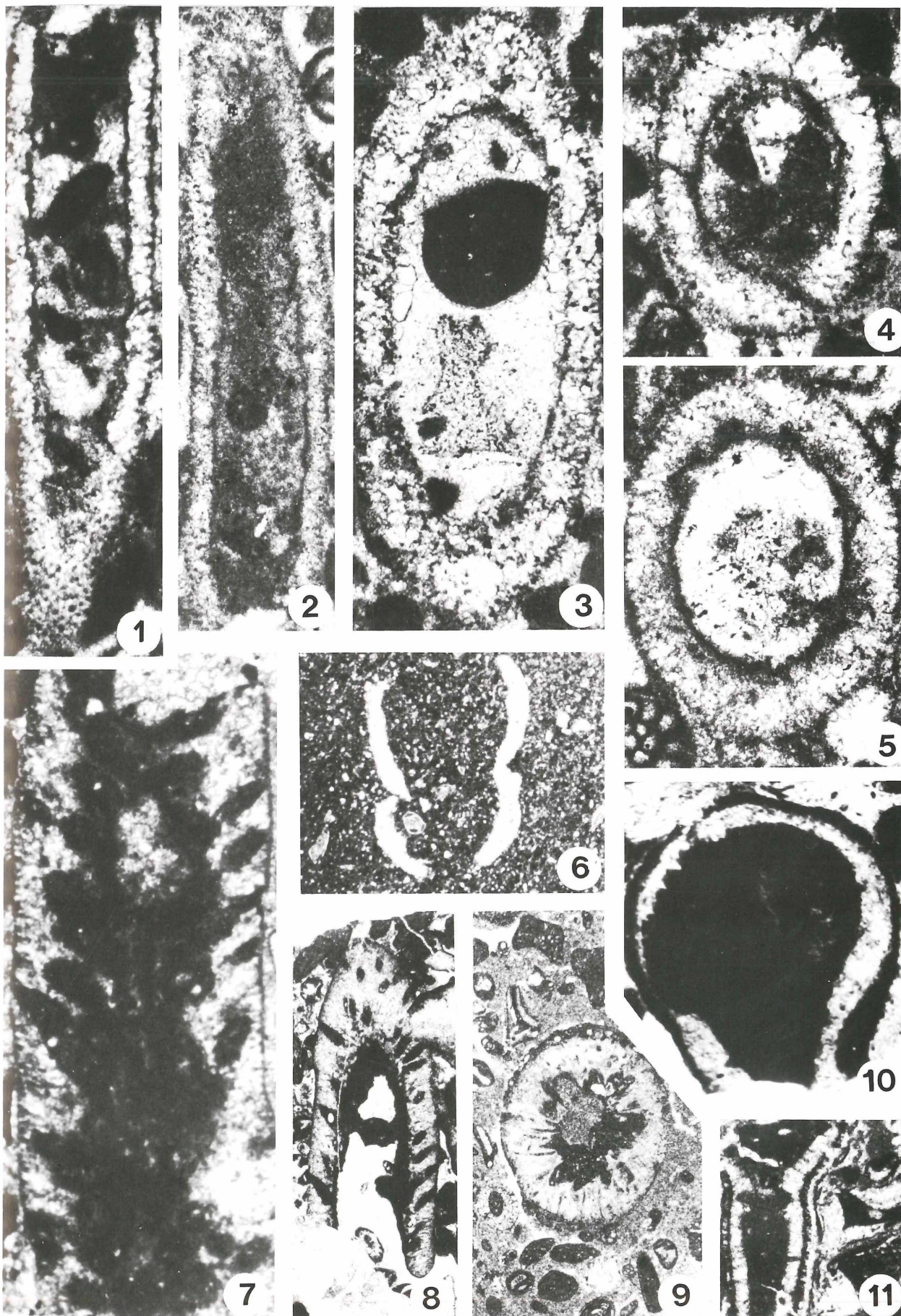
Fig. 10. Longitudinal-oblique section. Holotype. Sample 397J – Ghicin; x 48.

Fig. 11. Longitudinal-oblique section. Sample 397/16 – Ghicin; x 36.

All samples from the Resita – Moldova Noua zone. Figs. 1–5. Lower Aptian;  
Figs. 6, 8–11. Upper Barremian – Lower Aptian; Fig. 7. Upper Berriasian – Valanginian.



PLATE 7



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Zeitschrift/Journal: [Beiträge zur Paläontologie](#)

Jahr/Year: 1994

Band/Volume: [19](#)

Autor(en)/Author(s): Bucur Ioan I.

Artikel/Article: [Lower Cretaceous Halimedaceae and Gymnocodiaceae from Southern Carpathians and Apuseni Mountains \(Romania\) and the systematic position of the Gymnocodiaceae 13-37](#)