Dasycladalean algae from Upper Jurassic-Lower Cretaceous limestones of Piatra Craiului Massif (South Carpathians, Romania) and their relationship to paleoenvironment

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INTRODUCTION

During the Late Jurassic-Early Cretaceous, the dasycladalean algae flourished, with some species recording acmes during relatively short stratigraphic intervals (Bassoullet et al., 1978; Barattolo, 1991; Berger and Kaever, 1992; Granier and Deloffre, 1993; Bucur, 1999). As a rule, fossil algae ecology can be deduced by extrapolating environmental observations made on present-day calcareous algae. The latter populate various marine environments, from high-energy reefs to low-energy lagoons. They prefer tropical warm waters, around 20°C annual average values (Roux, 1995; De Castro, 1997; Valet, 1979).

Our study focuses on the relationship of some dasycladalean algae with their depositional environment. Based on sedimentary features and associated microfossils, we evidenced several depositional environments. Each of them favored the development of a variable number of species controlled by several ecological key-factors.

We have sampled four sections in the Piatra Craiului carbonate succession: Padina Închisă-Lehmann’s trail, West Vlăduşca-East Vlăduşca, Zaplaz-Lanţuri, and Padina Lăncii (Fig. 1). All the samples from these sections were investigated in order to describe the main type of microfacies and microfossils.

GEOLOGICAL FRAMEWORK

The 25 km-long, NE-SW oriented calcareous mountain crest forming the Piatra Craiului Massif is located in eastern part of the Southern Carpathians (Fig. 1), forming the western flank of a large synclinal unit (Popescu, 1966; Patrulius, 1969). On the top of the crystalline basement assigned to the Cumpâna and Leaota formations, a sedimentary succession consisting of Kimmeridgian-Lower Valanginian calcareous deposits is found in the Piatra Craiului Syncline (Bucur et al., 2009). Bajocian-Oxfordian terrigenous and carbonate rocks consisting of microconglomerates, sandstones and marly-limestones passing towards the top into radiolarites with marl and calciturbidite interlayers, and jaspers form the base of this succession (Popescu, 1966; Bucur, 1978; Bucur, 1980; Mészaros and Bucur, 1980; Beccaro and Lazăr, 2007). Next in the succession are white, massive or stratified limestones; when present, the layers are in the order of meter- to centimeter-decimeter- thick. The massive limestones consist of coral bioconstructions and fore-reef rudstones (Fig. 2a-b). They crop-out in lower part of the carbonate succession and correspond to the platform margin. Meters to centimeter-thick layered (peritidal) limestones developed in the upper part of the succession are rich in bioclasts (Fig. 2c-e; g-h) and show frequent fenestral structures (Fig. 2f). Within these peritidialites, we could identify all of the three depositional subenvironments (subtidal, intertidal and supratidal) described below. They migrate laterally and may present typical variations within the calcareous massif.

On the whole, the succession is interpreted as a shallowing upward prograding megasequence of Kimmeridgian-Lower Valanginian age (Bucur et al., 2009; Mircescu et al., 2013; Pleş et al., 2013) (Fig. 3).

Microfacies and microfossils

A number of 720 thin sections have been made and microscopically investigated; they allowed the separation of eight major microfossils types (MF type 1-MF type 8) (Table 1): coarse bioclastic rudstone, coral-microbial boundstone,
bioclastic-intraclastic grainstone with black pebbles, grainstone with regenerated ooids, fenestral bioclastic wackestone, bindstone with cyanobacteria, fenestral-bioclastic packstone/grainstone, and homogenous non-fossiliferous mudstone. MF type 1 and MF type 2 are the main component of reef slope and platform margin environments while MF type 3-MF types 8 are characteristic for peritidal environments (internal platform with high and low energy, intertidal, supratidal). The most important microfossils (foraminifera and dasyycladalea algae) are shown in Pl. I-VIII.

Microfacies type 1 (coarse bioclastic rudstone)

In the lower part of the studied sections, Kimmeridgian limestones are built-up of the typical rudstones of reef slope environments (Pleş et al., 2013). They are frequently associated with coral-microbial boundstones (MF type 2). Within the rudstones, poorly sorted angular-subangular clasts indicate limited transportation (Pl. II, Figs. 1, 2). Bioclasts consist of bivalve shells, gastropod tubes, juvenile ammonites and foraminifers (Pl. II, Figs. 3, 4).

Dasycladalean algae (Salpingoporella pygmaea and Clypeina sulcata) are also present, but with a relatively reduced species diversity. They seem to be dispersed into the bioconstructions internal sediment, or they occur as small fragments mixed with the reef detritus along the fore-reef slope.

Microfacies type 2 (coral-microbial boundstone)

The boundstones display peloidal bioclastic packstone-wackestone-type internal sediment (Pl. II, Figs. 5-7). Microbial crusts and encrusting organisms are important constituents, contributing significantly to the reinforcement of the reef.

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Table 1. The main microfacies identified in the studied zone and their relationship with the paleoenvironment.

| MF number | Microfacies description | Paleoenvironment | Illustration |
|-----------|-------------------------|------------------|--------------|
| 1         | Coarse bioclastic rudstone | Reef slope and platform margin | Plate II, Figs. 1-4 |
| 2         | Coral-microbial boundstone | Reef slope and platform margin | Plate II, Figs. 5-8 |
| 3         | Bioclastic intraclastic grainstone with black pebbles | High energy internal platform subtidal | Plate III, Figs. 1-6 |
| 4         | Grainstone with regenerated ooids | High energy internal platform subtidal | Plate III, Figs. 7-8 |
| 5         | Fenestral bioclastic wackestone | Low energy internal platform subtidal | Plate IV, Figs. 1-6 |
| 6         | Bindstone with cyanobacteria | Intertidal-supratidal | Plate V, Fig. 1 |
| 7         | Fenestral bioclastic packstone-grainstone | Intertidal-supratidal | Plate V, Figs. 7-8 |
| 8         | Homogenous non-fossiliferous mudstone | Supratidal | |

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Fig. 1. Location of sampled sections from Piatra Craiului Massif on the geological map of Piatra Craiului-Dâmboviciara area (modified after the geological map of Romania, scale 1: 50000, sheets 110a-d, Dimitrescu et al., 1971; Patrulius et al., 1971; Sândulescu et al., 1972 and Dimitrescu et al., 1974). A) Padina Închisă-Lehmann’s Trail section; B) Western Vlădușca-Eastern Vlădușca section; C) Zaplaz-Lanțuri section; D) Padina Lăncii section; 1-3) Quaternary deposits 4,5) Cenozoic deposits 6) Turonian-Maastrichtian 7) Uppermost Albian-Cenomanian 8) Albian 9) Aptian 10) Barremian 11) Hauterivian 12) Kimmeridgian-Lower Valanginian 13) Callovian-Oxfordian 14) Bajocian-Callovian 15) Magmatic rocks 16) Leaota metamorphic formation 17) Cumpăna metamorphic formation 18) Fault 19) Sampled sections.

Fig. 2. Outcrop aspects of the Upper Jurassic-Lower Cretaceous limestones from Piatra Craiului. A) Massif limestones in the lower part of Vlădușca section; B) Coral bioconstructions; C) Peritidal limestones in the middle-upper part of the Padina Închisă section; D) Rudist-bearing bioclastic wackestone, Padina Închisă section; E) Meter bedded limestones in the middle-upper part of the Vlădușca section (Scale: 1 m); F) Laminoid-fenestral limestones, Vlădușca section; G) Decimeter to meter bedded limestones in the upper part of the Zaplaz-Lanțuri section; H) Bioclastic limestones with gastropods, Zaplaz-Lanțuri section.
Dasycladalean algae from Piatra Craiului Massif

Fig. 3. Generalized stratigraphic succession of the Kimmeridgian-Lower Valanginian limestones from Piatra Craiului: 1) Corals; 2) Coral fragments; 3) Microbial crusts; 4) Echinids; 5) Peloids; 6) Bivalves; 7) Bryozoans; 8) Gastropods; 9) Dasycladalean algae; 10) Rivilariacean-type cyanobacteria; 11) Foraminifers; 12) Rudists; 13) Regenerated ooids; 14) Fenestral structures; 15) Black pebbles; 16) Roots; 17) Latest Albian-Cenomanian conglomerates; 18) Aptian breccia; 19) Oxfordian radiolarieties.

Legend

Fig. 3. Generalized stratigraphic succession of the Kimmeridgian-Lower Valanginian limestones from Piatra Craiului: 1) Corals; 2) Coral fragments; 3) Microbial crusts; 4) Echinids; 5) Peloids; 6) Bivalves; 7) Bryozoans; 8) Gastropods; 9) Dasycladalean algae; 10) Rivilariacean-type cyanobacteria; 11) Foraminifers; 12) Rudists; 13) Regenerated ooids; 14) Fenestral structures; 15) Black pebbles; 16) Roots; 17) Latest Albian-Cenomanian conglomerates; 18) Aptian breccia; 19) Oxfordian radiolarieties.

Dasycladalean algae, rivilariacean-type cyanobacteria (Rivilaria piæ), gastropods, coral fragments, sponges, and Bacinella-type structures are the biota identified in the bioclastic-intraclastic grainstones (Pl. III, Figs. 1-6). A millimeter-thick micritic rim is present around the dasycladalean fragments (Pl. III, Figs. 2, 3). We assume that the micritization took place in a low-energy, quiet environment, under the influence of microendoliths (Bathurst, 1966; Flügel, 2004). Subsequently, the dasycladalean algae were reworked and re-deposited in higher-energy environments.

The black pebbles (Pl. III, Figs. 1, 6) indicate stages of subaerial exposure of the carbonate platform as well as relative fluctuations of the sea level. According to Strasser (1984), three models apply to the formation of black pebbles: the first assumes that a black film could form around carbonate clasts in anoxic microenvironments within peritidal areas. A second model considers that organic matter in the sediments blackens the carbonate clasts during the uplift stages of the carbonate platform (Strasser, 1984; Leinfelder, 1987). A third scenario also involves organic matter, but this is adsorbed at the surface of calcretes during pedogenetic micritization processes (Strasser, 1984; Săsăran, 2006). The black pebbles may be reworked, or may be found in situ. In the studied deposits, the pebbles were reworked in the subtidal sediments.

In the Zaplaz-Lanţuri and Padina Lăncii sections, we have identified limestone levels pigmented with iron oxides. They are probably subaerially exposed subtidal carbonate deposits. Dasycladalean algae (frequent Clypeina sulcata and seldom Campbeliella striata) and rare foraminifers are the typical bioclasts in these deposits. Here we have also remarked a second black pebbles level.

Microfacies type 4 (grainstone with regenerated ooids)

The grainstones with broken and regenerated ooids are frequent in Padina Închișă section. They build-up a 10 m-thick level located on top of the black pebbles-bearing deposits. No bioclasts are present in these sediments (Pl. III, Figs. 7, 8). These limestones formed in high-energy environments, in marginal or internal areas of the shallow carbonate platform (Flügel, 2004).

Microfacies type 5 (fenestral bioclastic wackestone)

This type of microfacies contains the following sub-types: wackestone with dasycladalean algae, bioelastic wackestone with diceratid rudists and gastropods, bioelastic mudstone/wackestone (Pl. IV, Figs. 1-6). The bioclasts, represented by large
gastropods, rudists and cyanobacteria nodules are embedded in a muddy, micritic sediment (Pl. IV, Figs. 1, 2). The micritic sediment is intensely bioturbated. The abundance of gastropods and cyanobacteria nodules (Pl. IV, Figs. 1-4) indicates a lagoon-type, quiet, shallow environment (low energy internal platform subtidal environment).

**Microfacies type 6 (bindstone with cyanobacteria)**

In the Padina Inchișă section, the cyanobacteria may form small biocorstructions (Pl. V, Fig. 1). These contain laminarit stromatolitic structures consisting of very fine peloids alternating with very fine, laminitic, black micrite. Skeletal cyanobacterial stromatolites are associated with the micritic laminites; sometimes they may also build-up thrombolitic fabrics (Pl. V, Fig. 1).

**Microfacies type 7 (fenestral-bioclastic packstone/grainstone)**

The following sub-types are characteristic for MF type 7: fenestral pedoidal bioclastic wackestone/packstone, packstone with cuneoluid foraminifers, grainstone/packstone with micritized ooids and intraclasts (Pl. IV, Figs. 7-8; Pl. V, Figs. 2-8). The top of the studied sections consists of intertidal-supratidal limestones. On western flank of the Piatra Craiului Massif, these deposits are more than 300 m-thick, while on the eastern side they are only 250 m-thick. The bioclastic wackestone/packstone dominates (Pl. V, Figs. 2, 3). Abundant rivulariacean-type cyanobacteria are the main bioclasts present (Pl. V, Figs. 4, 5, 8) and they indicate restrictive environments. Rare bivalves, gastropods and cuneoluid foraminifers are also present. We have also noticed grains formed under high energy condition (ooids) that were afterwards reworked into intertidal environments and micritized (Pl. V, Fig. 6). In similar depositional environments, micritization processes are often associated with low carbonate sediment accumulation rates (Enos, 1983; Flügel, 2004).

**Microfacies type 8 (homogenous non-fossiliferous mudstone)**

This type of microfacies lacks microfossils almost entirely. Sometimes dolomitization is present, mainly located along fissures. In addition, we noticed diffuse structures resembling calcrites in the East Vlădușca section; they may include root tracks. Sometimes dolomitization is present, mainly located along fissures.

**The age of the studied deposits**

The micropaleontological assemblages identified in the white limestones from Piatra Craiului Massif (Pls. I, VI-VIII) point to a Kimmeridgian-Lower Valanginian age. Table 2 includes the identified foraminiferal and dasycladalean species, together with their generalized stratigraphic distribution.

The foraminifers *Labyrinthisa mirabilis* and *Paragonina caelinensis* are typical species for the Kimmeridgian-Lower Tithonian interval (Cuvillier et al., 1968; Bassoulet, 1997). They are associated with the algae *Salpingoporella pygmaea*, *Clypeina sulcata*, *Steinmannoporella kapeleensis*, *Campbelliella striata* and *Petrascula bursiformis*, another typical Kimmeridgian-Tithonian association (Fenninger and Hötzl, 1967; Granier and Deloffre, 1993; Senowbari-Daryan et al., 1994; Bucur, 1999; Schlagintweit and Ebl, 1999; Schlagintweit, 2004; Schlagintweit and Gawlick, 2005; Carras et al., 2006; Schlagintweit, 2011).

The foraminiferal association identified at the top of the succession is characterized by Berriasian-Lower Valanginian species such as *Protopeneroplis ultrasubgranulata*, *Pseudotextulariella courti*, *Haplophragmoides joukowskyi*, *Pfenderina neocomiensis*, or *Conicopeneroplis? balkanica* (Altiner, 1991; Bucur et al., 1995; Bucur, 1997; Peybernès, 2004; Ivanova and Kolodziej, 2010). The accompanying calcareous algae also indicate a Berriasian-Valanginian age: *Clypeina parasokalni*, *Salpingoporella annulata*, *Pseudocymopolia jurassica*, *Salpingoporella praturloni* (Farinacci and Radoičić, 1991; Granier and Deloffre, 1993; Massé, 1993; Schindler and Conrad, 1994; Bucur, 1999; Dieni and Radoičić, 1999; Moshammer and Schlagintweit, 1999; Schlagintweit et al., 2009).

**Relationship between dasycladalean algae and paleoenvironment**

Based on the identified microfacies types and the microfossils, we could separate three principal depositional environments: reef slope and platform margin, internal platform subtidal, intertidal and supratidal.

**Reef slope and platform margin environment**

In the lower part of the sampled sections, reef slope carbonate deposits were identified. They are represented by bioclastic rudstone, and boundstone with packstone-wackestone type internal sediment.

Most probably, the algal species identified in the reef rudstone deposits (*Clypeina sulcata*, *Salpingoporella pygmaea*) were reworked, as they are dispersed within the mass of grain flows along the fore-reef slope (Pl. VI, Figs. 1-4). We have identified *Petrascula bursiformis* only in the Padina Lâncii section. Because it is present in packstone-type internal sediment of a coral bioconstruction, we assume that this species is in situ (Pl. VI, Figs. 5-8). Other authors (Schlagintweit, 2011; Bucur and Săsăran, 2012) have described similar large dasycladelaeans from similar depositional environments.

**Internal platform subtidal environment**

Internal platform subtidal limestones identified in the studied sections formed in both high- and low energy platform environments. High energy subtidal carbonate rocks consist of bioclastic-intraclastic grainstones with black pebbles, or grainstones with regenerated ooids. In the Padina Inchișă, West Vlădușca, and Zaplaz-Lanțuri sections, these deposits are about 60 m-thick. This marker level located on top of the reef limestones can be followed along the whole western flank of the Piatra Craiului Massif.

In the internal platform high energy subtidal deposits, we have identified the following dasycladalean algae: *Campbelliella striata*, *Clypeina sulcata*, *Salpingoporella annulata*, *Salpingoporella pygmaea* and *Steinmannoporella kapeleensis* (Pl. VII). A micritic rim often surrounds *Clypeina sulcata* and *Salpingoporella pygmaea*. We assume that the micritization took place in a low-energy, quiet environment, under the influence of microendoliths. Subsequently, the dasycladalean algae were reworked and re-deposited in higher-energy environments.
Table 2. Stratigraphic distribution of foraminifera and dasycladalean algae identified in Piatra Craiului Massif.

| Taxa                        | Range | Kimmeridgian | Tithonian | Berriasian | Valanginian | Illustration |
|-----------------------------|-------|--------------|-----------|------------|-------------|-------------|
| Foraminifera                |       |              |           |            |             |             |
| Paragephyra                 |       |              |           |            |             |             |
| Cassidulina                 |       |              |           |            |             |             |
| Labyrinthina                |       |              |           |            |             |             |
| Protopeneplesia             |       |              |           |            |             |             |
| Pseudocymopolia             |       |              |           |            |             |             |
| Steinmanniporella           |       |              |           |            |             |             |
| Dasycladalean algae         |       |              |           |            |             |             |
| Salpingoporella pytnea      |       |              |           |            |             |             |
| Salpingoporella annulata    |       |              |           |            |             |             |
| Petravcula                  |       |              |           |            |             |             |
| Campbeelrelia               |       |              |           |            |             |             |
| Clypeina                    |       |              |           |            |             |             |
| Steinmanniporella kapelensis|       |              |           |            |             |             |
| Clypeina parasolkani        |       |              |           |            |             |             |
| Paracymopolia jurassica     |       |              |           |            |             |             |
| Salpingoporella praturloni  |       |              |           |            |             |             |

As a rule, *Steinmanniporella kapelensis* is present in deposits formed on carbonate platform margins (Bucur and Săsăran, 2012), as it is also the case in the Piatra Craiului area.

*Salpingoporella annulata* was identified in both normal marine (Jafrezo and Renard, 1979), and restrictive (Bucur and Săsăran, 2005) environments. Similarly, in Piatra Craiului this species is present in both open sea deposits (platform margin), and in restrictive, internal platform deposits.

In the upper part of the studied sections the limestones show typical features for restrictive environments (internal platform subtidal with low energy) with rare intercalations of higher energy deposits. The dasycladalean algae dominate the wackestone and fenestral packstone/grainstone facies types. They are represented by four main species: *Clypeina sulcata*, *Clypeina parasolkani*, *Salpingoporella praturloni* and *Pseudocymopolia jurassica* (Pl. VIII, Figs. 1-8). The micritic sediment is intensely bioturbated. In these limestones, we have identified numerous specimens of *Clypeina sulcata*. They occur in abundance as monospecific, whole-fossils in a wackestone microfacies and can be interpreted as being in situ. This species frequently prefers restrictive environments with high salinity (Conrad, 1977).

Favre and Richard (1927) have described *Clypeina sulcata* (as *Clypeina jurassica*) from lagoonal limestones, a typical restrictive environment.

*Salpingoporella praturloni* and *Pseudocymopolia jurassica* prefer external platform environments (Bucur and Săsăran, 2005), but they seem also to occur in high-energy open-marine internal platform settings; they have been identified at the top of the Padina Inchisă- Lehnmann’s trail section, in bioclastic wackestones, probably reworked from areas of higher energy sedimentation.

The intertidal and supratidal environments

The top of the studied sections consists of intertidal-supratidal limestones. On the western flank of the Piatra Craiului Massif, these deposits are more than 300 m-thick, while on the eastern side they are only 250 m-thick. Dasycladalean algae are almost completely absent. Within the micritic sediment, the rivulariacean-type cyanobacteria are either isolated, or incorporated in the fenestral sediment (Pl. VIII, Fig. 5). Occasionally, the cyanobacteria incorporate peloids or ostracods. *Rivularia moldavica* is the dominant species (Pl. VIII, Fig. 4). According to Săsăran et al. (2013), in the intertidal limestones from Piatra Craiului the rivulariacean-type cyanobacteria are the main producers of carbonate, under the circumstances of a progressive decrease of the accommodation space rate of formation in parallel with the progradation of the carbonate platform.

As a rule, dasycladalean algae from Piatra Craiului Massif consists of deposits formed in a wide range of depositional environments. They indicate a general transition from platform margin to internal platform carbonate deposits. Jointly with the progradation of the carbonate platform, the water became shallower. Therefore, in the internal areas of the carbonate platform, restrictive, lagoon- or intertidal...
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Plate 1. The most important foraminifera identified in the Upper Jurassic-Lower Cretaceous limestones from Piatra Craiului. Scale: 0.5 mm (Figs. 1-2); 0.25 mm (Figs. 3-7).

Fig. 1. *Parurgonina caelinensis* Cuvillier, Foury & Pignatti Morano, longitudinal section; Zaplaz-Lanţuri section, sample 652;
Fig. 2. *Labyrinthina mirabilis* Weynschenk, longitudinal-tangential section; Padina Lâncii section, sample 743;
Fig. 3. *Pseudotextulariella courtionensis* Brönnimann, oblique section; Padina Închisă section, sample 464;
Fig. 4. *Protopenepolpis ultragranulata* (Gorbatchik), subaxial and tangential sections; Lehmann’s Trail section, sample 621;
Fig. 5. *Haplophragmoides joukowskyi* Charollais, Brönnimann & Zaninetti, subequatorial section; Padina Închisă section, sample 464. Scale: 0.25 mm;
Fig. 6. *Pfenderina neocomiensis* (Pfender), oblique section; East Vlăduşca section, sample 350;
Fig. 7. *Conicopfenderina? balkanica* Peybernès, longitudinal-oblique section; Lehmann’s Trail section, sample 411.
Plate II. Slope and platform edge deposits in the lower part of the carbonate succession in Piatra Craiului. Scale: 1 mm.

Fig. 1. Bioclastic-peloidal rudstone with encrusting organisms and echinoderm plates; Padina Închisă section, sample 50 P;
Fig. 2. Coarse bioclastic grainstone/rudstone with microbial structures, encrusting organisms and bryozoans; West Vlădușca section, sample 125;
Fig. 3. Bioclastic rudstone. Bioclasts consist of encrusting organisms (Crescentiella morronensis), agglutinated-walled worm tubes, and bivalves; Zaplaz-Lanțuri section, sample 591;
Fig. 4. Bioclastic rudstone. Bioclasts consist of echinoderm plates, gastropods, bivalves, recrystallized coral fragments and encrusting organisms [Crescentiella morronensis (Crescenti)]; Padina Lăncii section, sample 686;
Figs. 5, 6. Coral-microbial boundstone with Crescentiella morronensis. Encrusting organisms are present together with the sediment between corals; Fig. 5: Padina Închisă section, sample 40 P; Fig. 6: West Vlădușca section, sample 138;
Fig. 7. Microsolenid boundstone with peloidal wackestone as internal sediment. Corals are bioeroded; Zaplaz-Lanțuri section, sample 582;
Fig. 8. Coral-microbial boundstone. Superposed crusts of calcareous sponges (Calcistella jachenhausenensis) and stromatolitic-microbial structures on a coral; Padina Lăncii section, sample 717 b.
**Plate III.** Characteristic microfacies of the high-energy internal platform subtidal carbonate deposits. Scale: 1 mm.

**Fig. 1.** Bioclastic-intraclastic grainstone with black pebbles; West Vlădușca section, sample 212c;

**Fig. 2.** Coarse bioclastic grainstone. Bioclasts consist of cyanobacteria, sponge fragments, bivalves and dasycladalean algae (*Clypeina sulcata*). A micritic envelope around bioclasts is developed; West Vlădușca section, sample 213;

**Fig. 3.** Bioclastic-intraclastic, fenestral packstone-grainstone with dasycladalean algae (*Salpingoporella pygmaea*) and bivalve fragments; Zaplaș-Lanțuri section, sample 630;

**Figs. 4, 5.** Coarse bioclastic grainstone with cyanobacteria, nerineid gastropods, bivalves and corals. Micritic envelopes around bioclasts; West Vlădușca section, sample 630;

**Fig. 6.** Bioclastic-intraclastic, fenestral grainstone with black pebbles; West Vlădușca section, sample 632;

**Figs. 7, 8.** Oolitic grainstone with broken and regenerated ooids. Rare bioclasts are represented by gastropods; Padina Închisă section, sample 490.

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Plate IV. Microfacies of low-energy internal platform subtidal carbonate deposits. Scale: 1 mm.

Fig. 1. Bioclastic-fenestral, bioturbated wackestone with gastropods; Padina Închisă section, sample 435;
Fig. 2. Bioclastic wackestone with diceratid rudists and other bivalve fragments and gastropods. Some cavities are filled with geopetal sediment; Padina Închisă section, sample 468;
Figs. 3, 4. Bioclastic wackestone/floatstone with coral fragments, dasycladalean algae, gastropods and cyanobacteria; Lehmann’s Trail section. Fig. 3: sample 621; Fig. 4: sample 621;
Figs. 5, 6. Bioclastic-intraclastic wackestone with dasycladalean algae (*Clypeina sulcata*); West Vlădușca section. Fig. 5: sample 197; Fig. 6: sample 197;
Figs. 7, 8. Bioclastic-intraclastic packstone-grainstone. Main bioclasts are represented by foraminifera. Intraclasts contain cyanobacteria nodules; East Vlădușca section, sample 288.
Plate V. Microfacies of intertidal-supratidal carbonate deposits. Scale: 1 mm.

Fig. 1. Microbial laminitic (stromatolitic) structures; Padina Închisă section, sample 454;
Fig. 2. Peloidal fenestral wackestone; West Vlădușca section; sample 245;
Fig. 3. Peloidal fenestral wackestone sharply overlain by a bioclastic-intraclastic grainstone with cyanobacteria; Lehmann’s Trail section, sample 415;
Fig. 4. Rivulariacean-type cyanobacteria (*Rivularia moldavica* Frollo); West Vlădușca section, sample 242;
Fig. 5. Rivulariacean-type cyanobacteria in a fenestral fabric, West Vlădușca section, sample 245;
Figs. 6, 7. Bioclastic-fenestral packstone-grainstone with micritized ooids and rivulariacean fragments; East Vlădușca section, sample 315;
Fig. 8. Intracrystal-bioclastic, fenestral packstone-grainstone with rivulariaceans and gastropods, East Vlădușca section, sample 316;
Plate VI. Dasycladalean algae from the reef limestones. Scale: 0.25 mm (Figs. 1-2; Fig. 4); 0.5 mm (Fig. 3; Figs. 7-8); 1 mm (Figs. 5-6).

Fig. 1. Clypeina sulcata (Alth), transverse section; Padina Închisă section, sample 30 P;
Fig. 2. Clypeina sulcata (Alth), tangential section; West Vlăduşca section, sample 79;
Fig. 3. Salpingoporella pygmaea (Gümbel), oblique section; Padina Închisă section, sample 40 P;
Fig. 4. Salpingoporella pygmaea (Gümbel), transverse-oblique section; West Vlăduşca section, sample 100;
Figs. 5-8. Petrascula bursiformis (Etallon); Padina Lâncii section, sample 721; Fig. 5: oblique and oblique-transverse sections; Fig. 6: tangential and oblique sections; Fig. 7: tangential section; Fig. 8: longitudinal section of a head fragment.
PLATE VI
Plate VII. Dasycladalean algae from the high-energy internal platform subtidal carbonates. Scale: 0.25 mm (Figs. 1-2, Fig.5); 0.5 mm (Figs. 3-4; Figs. 6-8).

Fig. 1. *Salpingoporella pygmaea* (Gümbel), oblique section; Padina Închisă section, sample 71 P;

Figs. 2, 3. *Salpingoporella annulata* Carozzi. Fig. 2: oblique section; Padina Închisă section, sample 464; Fig. 3: transverse and longitudinal oblique sections; Zaplaz-Lanţuri section, sample 628;

Fig. 4. *Steinmanniporella kapelensis* (Sokać and Nikler), transverse-oblique section; West Vlădușca section, sample 218;

Figs. 5, 6. *Chypeina sulcata* (Alth), Zaplaz-Lanţuri section. Fig. 5: transverse section, sample 650; Fig. 6: transverse and tangential sections, sample 651;

Figs. 7, 8. *Campbelliella striata* (Carozzi), Zaplaz-Lanţuri section. Fig. 7: oblique section, sample 630; Fig. 8: longitudinal-tangential section, sample 631.
Plate VIII. Dasycladalean algae from the low-energy internal platform subtidal carbonates. Scale: 0.25 mm (Figs. 1-5; Figs. 7-8); 0.5 mm (Fig. 6).

**Figs. 1, 2.** *Clypeina sulcata* (Alth.), tangential-oblique section; West Vlădușca section, sample 197;

**Figs. 3, 4.** *Salpingoporella annulata* (Carozzi), Padina Închisă section. Fig. 3: oblique section, sample 464; Fig. 4: transverse-oblique section, sample 464;

**Fig. 5.** *Clypeina parasolkani* Farinacci & Radoičić, transverse-oblique section; Padina Închisă section, sample 464;

**Fig. 6.** *Clypeina sulcata* (Alth.), longitudinal section cutting five verticils; West Vlădușca section, sample 197;

**Fig. 7.** *Pseudocymopolia jurassica* Dragastan, longitudinal section; Lehmann’s Trail section, sample 621;

**Fig. 8.** *Salpingoporella praturloni* (Dragastan), fragment of longitudinal section and *Protopeneroplis ultragranulata* (Gorbatchik), transverse section; Lehmann’s Trail section, sample 621;

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