LOWER CRETACEOUS LIMESTONES FROM THE NORTHERN PART OF PĂDUREA CRAIULUI (OSOIU HILL AND SUBPIATRĂ SECTIONS): BIOSTRATIGRAPHY AND PRELIMINARY DATA ON MICROBIAL STRUCTURES

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ABSTRACT. Two sections have been measured within the Lower Cretaceous deposits from the northern part of Pădurea Craiului: Osoiu Hill section and Subpiatră section. Thin sections representing more than 180 samples allowed us to present some results on the biostratigraphy, facies succession and the role of microbial structures in the genesis of these limestones. The Osoiu Hill section is dominated by fenestral limestones formed in the intertidal or in the shallow subtidal zone. Their formation is dominantly related to microbial mats. Based on foraminiferal assemblages we attribute a Lower Barremian age to these limestones. The succession in the Subpiatră section is dominated by shallow facies with rudists, corals and *Bacinella*. These limestones contain *Mesorbitolina texana* a foraminifer which indicate Gargasian age. A more dense spectrum of microbial structures characterize this section: thrombotic crusts, *Bacinella-Lithocodium* type structures, cryptic carbonate marine veneers and rivulariacean-like cyanobacteria. The microbial structures played an important role in the genesis of carbonate sediments and their lithification in the two sections.

Keywords: carbonate rocks, biostratigraphy, microbialites, microencrusts, Lower Cretaceous, Pădurea Craiului (Apuseni Mountains, Romania).

INTRODUCTION

This paper presents the preliminary results of our study on some carbonate deposits in the northern part of Pădurea Craiului massif, based on information provided by the measurement of two sections: Osoiu Hill (in the neighbourhood of Fâșca locality), and Subpiatră (located at about 2 Km south from the "Holcim" quarry, in the place known as Fântâna Rece (Fig.1)

A general view of the succession of Cretaceous deposits of Pădurea Craiului was given by Patrulius (in Ianovici et al., 1976). Additional contribution was provided by Dragastan et al. (1989), Bucur et al. (1993), Bucur & Cociuba (1996, 1998), and Cociuba (1999, 2000). Establishing a clear stratigraphical succession of the Lower Cretaceous in Pădurea Craiului is not straightforward, as proven by the two main opinions expressed in the stratigraphical schemes elaborated by Dragastan et al. (1989) and Dragastan & Ciobanu (2002) on the one hand, and by Bucur & Cociuba (1988), Cociuba (1999, 2000), Bucur (2000) and Bucur & Cociuba (2001) on the other. The current paper adopted the latter point of view.

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Fig. 1 – Location of the studied area, with emplacement of the two sections: Subpiatra (1) and Osoiu Hill (2)

SUCCESSION AND BIOSTRATIGRAPHIC REMARKS

1. Osoiu Hill Section

This section has been measured along 87 m thickness (Fig. 2). A total number of 83 samples has been collected, which have been investigated in thin sections.

The succession is dominated by fenestral limestones basically formed in the intertidal (the lower part of the succession), or in the shallow subtidal zone (the middle part of the succession). The upper part mainly consists of micrites, often of a fenestral and laminitic type.

The intertidal facies are represented by: peloidal fenestrate grainstone, fenestral grainstone/packstone, laminated wackestone/packstone, fenestral wackestone, mudstone/wackestone and fenestral mudstone. Peloids are abundant. Sometimes also micritic intraclasts are present. Bioclasts are represented by miliolids and other small foraminifers, ostracods, fragments of gastropods and rare fragments of bivalves (rudists). Rivulariacean-type cyanobacteria are present but not abundant. The fenestral lamination, the geopetal sediment, the meniscus- and stalactitic-type cement represent the specific features of these deposits.

The shallow subtidal facies are represented by *Bacinella* bindstone and wackestone/packstone with foraminifers and algae. Ostracod rests, fragments of bivalves and gastropods, as well as frequent rivulariacean-type cyanobacteria were also noticed.

Fig. 2 - Osoiu Hill section. 1 – grains (oids excepted); 2 – ooids; 3 – gastropods; 4 – tepee structures; 5 – laminitic structures; 6 – fenestral structures.

The ooids are common components in these limestone, leading to ooidic grainstone sequences often overlaying the sediments in their base along erosional surfaces (Pl.III, figs. 2, 5; Pl.IV). The high hydrodynamic regime often resulted in the formation of brecciated structures (Pl.III, fig.4). The fenestral (Pl.III, figs. 1-3) and laminitic (Pl.III, fig.5; pl.IV) structures prove the interference of the shallow subtidal facies with the intertidal ones.

The micrites in the top of the succession mainly contain rivulariacean-type cyanobacteria, small foraminifers, ostracods and rare fragments of gastropods. The deposits often show fenestral and laminitic structures; they were probably formed at the border within the shallow subtidal and intertidal zones.

A relatively scarce micropaleontological association was found within the whole succession. The following dasyclad algae and foraminifers have been identified: *Salpingoporella muehlbergii* (LORENZ), *Falsolikanella danilovae* (RADOIČIĆ), *Clypeina* sp., *Actinoporella* sp., *Paracoskinolina? jourdanensis* (FOURY & MOULLADE) (Pl.III, figs.7-8), *Pseudolituonella gavonensis* FOURY, *Pfenderina globosa* FOURY (Pl.III, fig.6), *?Earlandia* sp., *Charentia* sp., *Vercorsella* sp., *Belorussiella* sp., *Patellovalvulina* sp., and *Dobrogeolina* sp.

Based on the association with *Paracoskinolina? jourdanensis*, *Pfenderina globosa* and *Pseudolituonella gavonensis* (Foury & Moullade, 1966; Foury, 1968; Arnaud-Vanneau, 1980), we attribute a Lower Barremian age to these limestones. They correspond to the middle part of the Coposeni Member within the Blid Formation (sensu Cociuba, 2000).

2. Subpiatră Section

The section was measured along 120 m thickness. A total of 99 samples were collected and studied in thin section. In its lower third, the succession is interrupted by a fault. For studying the deposits developed above the fault, two distinctive successions (A and B) located at a lateral distance of 20-30 m one from each other, have been measured (Fig.3).

The succession is dominated by shallow facies with rudists, corals and *Bacinella*. The lower part, the first 45 m above the base, mainly consists of rudist boundstone and *Bacinella* bindstone. Besides, foraminifers (orbitolinids, encrusting foraminifers, miliolids and other small benthic foraminifers), fragments of corals, gastropods and echinids, ostracods, rare dasyclads and rivulariacean-type cyanobacteria are present.

Associated to the two dominating facies types, are peloidal-fenestral grainstone, packstone and packstone/grainstone, coarse grainstone with fragments of rudists or with orbitolinids. The bioclasts are generally the same: fragments of rudists, gastropods, echinoderms, corals, rare ostracods, foraminifers (mainly orbitolinids, miliolids and encrusting foraminifers). Dasyclads are more frequent in the granular-bioclastic varieties, being accompanied by red algae (Solenoporaceans and Peyssonneliaceans). Rivulariacean-like cyanobacteria are a less abundant, but omnipresent component.

The middle part of the succession (of about 40 m length) is dominated by coarse grainstone and bioclastic packstone/grainstone with fragments of corals and rudists, gastropods, echinoderm debris, orbitolinids and rare dasyclads. Part of this succession, about 15-20 m length, is dominated by the two facies, rudist boundstone and *Bacinella* bindstone. Coral boundstones occur at several levels. Frequently, besides *Bacinella* also *Lithocodium* is present. Rivulariacean-type cyanobacteria, even if in small amounts occur constantly, in a similar pattern as in the lower part of the succession.

Finally, the upper part of the succession, on a length of about 30-35 m, consists of bioclastic grainstone/packstone, with the relatively frequent orbitolinids starting to agglutinate sponge spicules. The orbitolinids are associated by encrusting foraminifers, solenoporacean red algae (*Marinella*) and rare fragments of dasyclads, *Lithocodium* nodules, fragments of rudists, worm tubes and abundant, small fragments of echinoderms. All these features point to a deepening trend of the depositional environment (slope, or upper slope facies). The presence of several coral boundstone levels indicate specific trends of the environment's evolution towards the platform border. Such a level allows the lateral correlation of the deposits in the two complementary sections (Fig.3).

The micropaleontological association in the Subpiatră section consists of the following calcareous algae and foraminifers: *Bakalovaella elitzae* (BAKALOVA) (Pl.I, fig.3), *Salpingoporella* cf. *patruliusi* (BUCUR) (Pl.I, fig.5), *Salpingoporella* sp., *Neomeris* sp. (Pl.I, fig. 4), *Polystrata alba* (PFENDER), *Marinella lugeoni* PFENDER, *Giraliarella? prismatica* ARNAUD-VANNEAU, *Sabaudia minuta* (HOFKER) (Pl.I, fig.2), *Mesorbitolina texana* (ROEMER) (Pl.I, fig.1), *Troglotella incrustans* Wernli & FOOKES (Pl.II, fig.4), *Everticyclammina* sp., *Vercorsella* sp., *Novalesia* sp., *Voloshinoides* sp., *Charentia* sp., *Mayncina* sp., *Nautiloculina* sp., *Dobrogelina* sp., *Meandrospira* sp., and *Orbitolinopsis* sp. The microproblematic *Coptocampylodon fontis* (PATRULIUS) (Pl.I, fig.5) was also identified in this association.

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The presence of *Mesorbitolina texana* is a clear indicator that the deposits can not be older than the Gargasian. According to the adopted stratigraphical scheme of the Pădurea Craiului region (Cociuba, 2000), carbonate deposits of this age are known within the Vârciorog Formation, being previously attributed to the so-called “Upper Pachyodont Limestones” (*fide* Patrulius, in Ianovici et al., 1976). It is worth to mention that in the type-section of the Vârciorog Formations these limestones are not more than 15-20 m in thickness, while in the Subpiatră section they are 120 m thick. Taking into account also the allochthonous feature of the corresponding deposits at Vârciorog – resembling slope-flows towards deeper basin areas, we consider that the Subpiatră section preserves *in situ* the platform which had generated the flows. Additional research is needed for defining the detailed configuration of this platform.

PRELIMINARY REMARKS ON MICROBIAL STRUCTURES

As proven by numerous studies (e.g. Leinfelder et al., 1993; Schmid, 1996; Helm & Schülke, 1998; Dupraz & Strasser, 1999; Ouribane et al., 2000; Schlagintweit & Gawlik, 2003), microbialites have played a significant role during Jurassic – especially the Upper Jurassic - in the Tethysian area; sometimes they lead to the formation of microbialitic reefs proper. On the contrary, very little information on the deposits of microbial origin of the Lower Cretaceous is available: e.g. Masse (1969, 1972, 1979) has described deposits and structures basically of microbial origin as “cryptalgal structures”; Neuweiler (1993) studied Albian microbialites from Spain.

Even if currently no microbial reefs have been discovered in the Lower Cretaceous limestones, it is obvious the microbialites and microencrusts have played a significant role during this interval as well (as indicated by the structures described in Urgonian deposits by Masse, 1969, 1979).

The two sections investigated in the present paper characterise two distinctive sedimentation domains, each including microbial structures but showing specific features.

1. Osoiu Hill Section

The formation of the limestones in Osoiu Hill, in the intertidal zone, is dominantly related to microbial mats, the process being followed by desiccation and lithification that lead to the fenestral-laminitic character (Pl.III, figs.1, 3; Pl.IV). The increase of hydrodynamic energy often resulted in the “burial” of the microbial mats by granular sediments along erosional surfaces (Pl.III, fig.2; Pl.IV). Besides the microbial mats, assumed to represent the main microbial-related structures in these limestones, some other structures of secondary importance have been identified. For example, some larger intraclasts formed as a result of the break of the penecontemporaneous sediment, have been subsequently surrounded by small-sized thrombolitic crusts. Similarly, some microbialitic oncoids are sometimes associated with microbial mats. Rivulariacean-type cyanobacteria are present along the whole succession, *Bacinella* bindstone being scarce.

2. Subpiatră Section

A more diverse spectrum of microbial structures (including microencrusters) characterize this section. The rudist boundstone frequently contains microbialitic crusts binding the rudist skeletons (Pl.II, fig. 5). They are often associated with micritic peloids of microbial nature and with a fenestral-type microbialitic sediment developed inside the rudist tests. Such microbial crusts most probably were formed soon after the sediment burial, when the rudist skeletons have been surrounded by microbial colonies that also are assumed to have caused the endolithic perforations (Pl.II, fig.5) in the rudists' tests (Neuweiller, 1993).

Coral boundstones are often covered by thrombolitic crusts with a relatively limited extent. Sometimes the coral interseptal(?) spaces were post mortem invaded by tubular cyanobacteria (Pl.II, fig.3).

However, in the Subpiatră section the largest extent belongs to the *Bacinella*-type structures (Pl.II, fig.1). They consist of massif banks with the voids of the *Bacinella* network embedded in micritic peloids and various types of bioclasts. *Bacinella* is also the main structure type that binds the bivalve tests within some rudist boundstones. In some case it is associated with *Lithocodium*-type structures and with the foraminifer *Troglotella*, the latter producing perforations in the rudist skeletons (Pl.II, fig.4). Camoin & Maurin (1988) consider bacinelloid structures as microbial products, this being reinforced by Uță & Bucur (2003). According to Neuweiller (1992), *Bacinella* (bacinelloid *Lithocodium* in the terminology of Neuweiller) together with other algae and microbes "is a major constituent of thrombolitic mud mounds". Neuweiller described massive (8 m) bacinelloid *Lithocodium* boundstones in Albian deposits in Spain, demonstrating its role in baffling and binding, and underlining the major contribution in the micrite production.

A special type of microbial structures occurring in the limestones of the Subpiatră section is represented by the micritic structures formed inside the rudist skeletons (Pl.II, fig.2); it closely resembles the "cryptic carbonate marine veneers" described by Riding (2002).

The encrusting foraminifers are many times associated with *Bacinella*/*Lithocodium* (Pl.I, fig.7), or with "Tubiphytes"-type structures (Pl.I, fig.8) in the frame of crusts that have played a role during the sediment lithification. Finally, another case are the rivulariacean-type cyanobacteria (Pl.I, fig.6), which even if in small amounts occur constantly along the whole succession.

CONCLUSIONS

The study of two measured sections within the Lower Cretaceous limestones in the northern part of Pădurea Craiului has shown that these deposits belong to 1) Lower Barremian (Osoiu Hill section) with *Paracoskinolina? jourdanensis*, and 2) Upper Aptian (Gargasian) (Subpiatră section) with *Mesorbitolina texana*.

The microbial structures (microbial mats, thrombolitic microbialites, diverse types of microbial crusts and microencrusters) have been identified in both sections, as contributors to the sediment formation (mainly via the microbial mats, in the case of the intertidal limestones from Osoiu Hill, and via the *Bacinella* bindstone in the Subpiatră section), but also as factors of the carbonate sediments' consolidation and cementation in both sections.

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PLATES

Plate I

- Fig. 1 – *Mesorbitolina texana* (ROEMER). Longitudinal section passing through the embryonic apparatus. Sample 7683 (Subpiatră section), x 60.
- Fig. 2 – *Sabaudia minuta* (HOFKER). Longitudinal-tangential section cutting the embryonic apparatus. Sample 7738 (Subpiatră section), x 60.
- Fig. 3 – *Bakalovaella elitzae* (BAKALOVA). Oblique section. Sample 7684 (Subpiatră section), x 30.
- Fig. 4 – *Neomeris* sp. Sample 7804 (Subpiatră section), x 60
- Fig. 5 – *Salpingoporella* cf. *patrulusi* BUCUR (fragment in oblique section), and *Coptocampylodon fontis* PATRULIUS (several transverse sections). Sample 7685 (Subpiatră section), x 30.
- Fig. 6 – Rivulariacean-type cyanobacteria. Sample 7691 (Subpiatră section), x 30.

Fig. 7 – *Bacinella irregularis* RADOIČIĆ and *Lithocodium aggregatum* ELLIOTT, encrusted by a pseudoalveolar foraminifer. Sample 7676 (Subpiatră section), x 30.

Fig. 8 – Agglutinated foraminifer encrusted by “*Tubiphytes*” and micritic microbial crusts. Sample 7686 (Subpiatră section), x 30.

Plate II

Fig. 1 – *Bacinella irregularis* RADOIČIĆ. Sample 7689 (Subpiatră section), x 15.

Fig. 2 – Micrite of microbial origin formed inside and outside of a rudist skeleton. Sample 7673 (Subpiatră section), x 15.

Fig. 3 – Tubular cyanobacteria in a coral fragments. Sample 7707 (Subpiatră section), x 60.

Fig. 4 – Rudist skeleton perforated by *Troglotella incrustans* WERNLI & FOOKES hosted by *Bacinella-Lithocodium*. Sample 7705 (Subpiatră section), x 15.

Fig. 5 – Rudist fragment covered by microbial micrite. Note also the endolithic perforations of the bivalve shell field with the same type of micrite surrounding the shell. Sample 7712 (Subpiatră section), x 15.

Fig. 6 – *Pfenderina globosa* FOURY. Transverse-oblique section. Sample 7780 (Osoiu Hill section), x 60.

Fig. 7-8 – *Paracoskinolina ? jourdanensis* FOURY & MOULLADE. Longitudinal (7) and transverse (8) sections. Sample 7806 (Osoiu Hill section), x 30.

Plate III

Fig. 1 – Fenestral limestone with micritic and peloidal deposit inside fenestrae. Sample 7829 (Osoiu Hill section), x 7,5.

Fig. 2 – Laminae of peloidal fenestrate grainstone with large micritic oncoids, separated by irregular micritic crusts. Sample 7832A (Osoiu Hill section), x 10.

Fig. 3 – Peloidal fenestrate micrite (fenestral microbial mat). Note the stalactitic cement, and the stalactitic microbial veneers on the roof of fenestrae. Sample 7847 (Osoiu Hill section), x 20.

Fig. 4 – Microbreccia in a micritic-peloidal fenestrate limestone. Sample 7829 (Osoiu Hill section), x 20.

Fig. 5 – Laminitic sequence with fine micritic laminae in the lower part, followed by coarser laminae of peloidal grainstone. Sample 7833 (Osoiu Hill section), x 7,5.

Fig. 6 – Flat-pebbles microbreccia in a supratidal laminitic limestone. Sample 7834 (Osoiu Hill section), x 7,5.

Plate IV

Fig. 1 – Intertidal-supratidal small cycle: upper intertidal-lower supratidal peloidal fenestrate mud (microbial mat) eroded by small intertidal channel field with peloidal-oidic sediment. Sample 7832B (Osoiu Hill section), x 7,5.

Plate I

Plate II

Plate III