New data on the Upper Jurassic – Lower Cretaceous limestones from Bihor Mountains: case study of Gârda Seacă - Hodobana region, Romania

Valentin TURI^{1,2}, Emanoil SĂSĂRAN^{1*} & Ioan I. BUCUR¹

¹Department of Geology, “Babeş-Bolyai” University, Kogălniceanu 1, 400084 Cluj-Napoca, Romania.

²Faculty of Geology and Geophysics, University of Bucharest, Traian Vuia 6, Bucharest, Romania.

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ABSTRACT. This study reconsiders problems regarding lithological succession, facies, and carbonate microfacies, and the biostratigraphic markers of the Upper Jurassic-Lower Cretaceous carbonates from the Bihor Mountains. Three types of facies (external marginal, subtidal, and peritidal) were separated for the Upper Jurassic, and two (coastal-peritidal and open shelf) for the Lower Cretaceous carbonates. The micropaleontological assemblages identified contain species that allow the separation of the two formations of different age: *Labyrinthina mirabilis*, *Kurnubia palastiniensis*, *Neokilianina rahonensis*, *Chypeina sulcata* (Kimmeridgian-Lower Tithonian) and *Parakoskinolina? jourdanensis*, *Montseciella arabica*, *Palorbitolina lenticularis*, *Falsolikanella danilovae* (Barremian-Lower Aptian). Field observations and data obtained from studies of thin sections and polished slabs indicate that a large part of the Triassic (Ladinian-Lower Carnian) and Lower Cretaceous limestones from Gârda Seacă-Hodobana region, delimited on the geological maps 1:50.000 scale, sheets 56b (Poiana Horea) and 56d (Avram Iancu), belongs in fact to the Upper Jurassic carbonate succession.

Key words: Carbonate microfacies and facies, biostratigraphy, Upper Jurassic-Lower Cretaceous limestone, Bihor Mountains, Romania.

INTRODUCTION

The study area is situated in the Bihor Mountains, along the Gârda Seacă Valley, near Hodobana village (Fig. 1). The geologic units that outcrop in this region belong to the so-called Bihor autochthonous that is overthrust by the Codru nappe system (Bleahu, in Ianovici et al., 1976; Săndulescu, 1984; Schmid et al., 2008). This part of the Bihor Mountains was previously studied by Bleahu (1954), Ianovici et al. (1976), Bleahu et al. (1981), Balintoni (1997), Dragastan et al. (1986), and Balintoni and Puşte (2002).

The formations studied are part of the Permo-Mesozoic sedimentary succession of the Bihor unit, represented here only by Lower Triassic to Lower Cretaceous deposits, as mapped on the 1:50.000 scale geological maps (Dimitrescu et al., 1977; Bleahu et al., 1980) (Fig. 1).

The Lower Triassic is made up of terrigenous deposits covered by Anisian dolomites, Ladinian terrigenous and limestone deposits, and Ladinian-Lower Carnian Wetterstein type limestones (Patrulius et al., 1971; Ianovici et al., 1976; Dimitrescu et al., 1977; Bleahu et al., 1980; Mantea 1985). For the Upper Jurassic-Lower Cretaceous deposits from the south-central part of the Bihor Mountains (between Crişul Pietros and Gârda Seacă valleys), Dragastan et al. (1986) distinguished the following formations: (1) Valea Crişanului (Oxfordian-Tithonian); (2) Albioara (Oxfordian?-Tithonian); (3) “Lower bauxite Formation” (Upper Tithonian-Berriasian); (4) Glăvoiu (Middle Berriasian-Hauterivian); (5) Hodobana (Berriasian-

Hauterivian); (6) Blid (Barremian-Lower Aptian) and (7) “Upper bauxite Formation” (Lower Barremian). It is worth noting that only the Valea Crişanului (supposedly a recent synonym for the Cornet Formation), Albioara, and Blid formations are easy to map in the field.

MATERIALS AND METHODS

This study is based on mapping activities carried out in the Hodobana-Gârda Seacă area and on 352 limestone samples collected from locations referred on the 1:50.000 geological maps as Ladinian-Carnian, Late Jurassic, and Early Cretaceous in age. Thin sections and polished slabs were made from these samples for microfacies and micropaleontological studies. The sections were analyzed using a Zeiss Stemi-2000C stereomicroscope and a Zeiss-Axioscope petrographic microscope. The microphotographs were taken with a Canon Powershot A640 digital camera.

JURASSIC CARBONATE MICROFACIES AND FACIES

Three main facies associations were separated for the Upper Jurassic succession (from base to top): 1) shallow marine facies from carbonate platform margin (external platform), 2) subtidal/lagoonal facies, and 3) peritidal/coastal facies (Fig. 2; Pls. I-III).

*Correspondence: E. Săsăran: emanoil.sasaran@ubbcluj.ro

Fig. 1. Location and geological setting of the study area.

- 1: Arieșeni Nappe; 2: Gârda Nappe; 3: Barremian-Aptian undivided Urgonian-type limestones; 4: Upper Jurassic biogenic reefs and oncoidic limestones; 5: Lower Jurassic conglomerates, sandstones, shales, marls and limestones; 6: Ladinian-Lower Carnian Wetterstein type limestones; 7: Ladinian sandstones, shales, breccia and limestones; 8: Anisian dolomites and Werfenian conglomerates, sandstones and shales; 9: Metamorphic rocks; 10: Quaternary deposits; 11: Faults; 12: Thrust front; 13: Samples location; 14: Apuseni Mountains; 15: Eastern Carpathians; 16: Southern Carpathians; 17: Codru Moma Mountains; 18: Pădurea Craiului Mountains; 19: Vlădeasa Mountains; 20: Bihor Mountains; 21: Gilău Mountains; 22: Muntele Mare Mountains; 23: Trascău Mountains; 24: Studied area.

Shallow marine facies from carbonate platform margin (external platform)

These facies are represented by bioconstructions and bioclastic banks (Pl. I, Figs. 1, 2). The bioconstructions are made-up mainly by corals and sponges, with some contribution from microbial crusts, which are incrusting other bioclasts and fill up the internal spaces of the framework (Pl. I, Fig. 1). The most characteristic microbial macrostructures are the dome-like hemispheroids and layered structures. Sindepositional cementation (radial type cement) strengthens the reef framework, and a series of encrusting microorganisms are also present [*Crescentiella moronensis* (CRESCENTI), *Iberopora bodeuri* GRANIER & BERTHOU, *Lithocodium aggregatum* ELLIOTT, *Thaumatoporella parvovesiculifera* (RAINERI), *Koskinobullina socialis* CHERCHI & SCHROEDER, *Radiomura cautica* SENOWBARI-DARYAN & SCHÄFFER, *Bacinella irregularis* RADOIČIĆ, bryozoans and encrusting foraminifera].

The internal sediment between bioconstructions is represented by intraclastic-bioclastic grainstone or intraclastic-bioclastic packstone/wackestone, and contains

Crescentiella moronensis (CRESCENTI), *Mercierella dacica* DRAGASTAN, sponges, bryozoans, echinoid fragments, molluscs, annelid tubes, benthic foraminifera, udoteacean algae (*Nipponophycus* sp.), and rare dasycladalean algae.

Fig. 2. Generalized stratigraphic section through the Upper Jurassic-Lower Cretaceous limestone from Hodobana-Gârda Seacă area (Bihor Mountains). 1: Bioconstructions with corals and sponges; 2: Dasycladalean algae; 3: Fenestral structures; 4: Bauxitic deposits.

The bioclastic banks are represented by granular bodies, intercalated with packstone with sponge spicules, or coral bioconstructions. The clasts of these bodies are of arenitic size and have subangular to rounded shapes (Pl. I, Fig. 2), suggesting a high hydrodynamic energy depositional environment. The most common facies are oncoidic-intraclastic grainstone, intraclastic-bioclastic grainstone, and intraclastic-bioclastic packstone. Intraclasts and reef clasts (boundstone with corals and sponges, boundstone with microbialites) are the main components of these facies. Other bioclasts, like echinoid fragments, bryozoans, mollusc fragments, and foraminifera (including miliolids) can also be recognized. Intraclasts are frequent and have predominantly rounded shapes. These facies contain also some ooids, peloids, and oncoids. Based on the predominantly reef related composition, these sediment bodies were interpreted as bioclastic shoals on the external platform. The association of bioconstructions with bioclastic shoals and the presence of packstones with sponge spicules indicate an external environment of a carbonate platform margin (e.g., Flügel, 2004).

Subtidal/lagoonal facies

A gradual transition from bioconstructions to the subtidal/lagoonal deposits can be noticed by the increase in “muddy” subtidal intercalations. The most representative facies are the oncoidic-bioclastic wackestone and mudstone with normal marine or restrictive fauna and flora (Pl. I, Figs. 3, 4).

In most of the cases, the subtidal limestones are represented by bioturbated peloidal-bioclastic mudstones. The fauna and flora are very diverse and represented by corals, sponges, echinoids, molluscs, large benthic foraminifera, green algae (dasycladales), and rivulariacean-type cyanobacteria. The benthic foraminifera and dasycladalean algae are the most characteristic biotic elements of this sub-environment and they were used for assigning the age of the limestones. Oncoids, peloids, intraclasts, and granular aggregates are other components associated with bioclasts, all included in a micritic matrix. All these peculiarities point towards a normal marine environment, with low hydrodynamic energy and shallow waters. The most representative facies are mudstone/wackestone with dasycladales and wackestone/packstone with dasycladales and foraminifera (Pl. I, Fig. 3). In restrictive conditions, a micritization of the bioclasts and a low diversity of fauna and flora can be observed. Cyanobacteria are dominant here (Pl. I, Fig. 4), indicating an isolation of the depositional environment, but some foraminifers, small gastropods, ostracods, and microproblematica (*Bacinella irregularis* RADOIČIĆ and *Lithocodium aggregatum* ELLIOTT) are also present. Very often the irregular growth of cyanobacteria has led to the developing of fenestral structures (Pl. I, Fig. 4), and laminar cyanobacterial coatings can be seen around oncoids and granular aggregates.

The micropaleontological assemblage identified in this depositional environment contains calcareous algae [*Solenopora* sp. (Pl. II, Fig. 1), *Campbelliella striata* (CAROZZI) (Pl. II, Fig. 2), *Salpingoporella annulata* CAROZZI (Pl. II, Fig. 3), *Salpingoporella pygmaea* (GÜMBEL) (Pl. II, Fig. 4), *Salpingoporella* sp., *Clypeina sulcata* (ALTH) (Pl. II, Fig. 5), *Nipponophycus ramosus* YABE & TOYAMA, *Thaumatoporella parvovesiculifera*

(RAINERI)], foraminifera [*Labyrinthina mirabilis* WEYNSCHENK (Pl. II, Fig. 6), *Parurgonina caelinensis* CUVILLIER, FOURY & PIGNATTI MORANO (Pl. II, Figs. 7, 10), *?Parurgonina* sp., *Neokilianina rahonensis* (FOURY & VINCENT) (Pl. II, Fig. 8), *?Everticyclammina* sp. (Pl. II, Fig. 9), *Kurnubia palastiniensis* HENSON (Pl. II, Fig. 11), *Redmondoides lugeoni* SEPTFONTAINE, *Andersenolina* sp., *Andersenolina alpina* (LEUPOLD), *?Pseudocyclammina* sp., *Pseudocyclammina lituus* YOKOYAMA, *?Charentia* sp., *Mohlerina basiliensis* (MOHLER), *Coscinophragma* sp.], rivulariacean-type cyanobacteria and microproblematica [*Bacinella irregularis* RADOIČIĆ, *Radiomura cautica* SENOWBARI-DAYAN & SCHÄFFER, *Lithocodium aggregatum* ELLIOTT, *Crescentiella moronensis* (CRESCENTI)], corals, sponges, bryozoans, crinoids, echinoids, gastropods, and ostracods.

The presence of carbonate grains (bioclasts, peloids, oncoids, intraclasts) in a micritic matrix and the presence of bioturbations indicate that these facies belong to a subtidal marine environment (Ginsburg, 1975, Shinn, 1983a; Hardie and Shinn, 1986; Tucker and Wright 1990; Pratt et al., 1992).

Peritidal/coastal facies

These facies are predominantly found in the upper part of the Jurassic succession. The facies and facies association characteristic for the peritidal environment were separated for the three depositional sub-environments: subtidal, intertidal, and supratidal.

a) Subtidal sub-environment (tidal littoral bars)

The separation of this sub-environment is based on textural, structural, diagenetic, and compositional criteria. The biotic elements are typical for the marine environment, and some remobilized fossils from adjacent intertidal and supratidal areas can be recognized (e.g., ostracods, gastropods, and small bivalves with thin shells). The most characteristic bioclasts are corals, sponges, echinoid fragments, bivalves, large benthic foraminifera, dasycladalean algae, and rivulariacean type cyanobacteria (Pl. I, Fig. 5). A micritic coating, sometimes made up entirely of cyanobacteria, can be seen around these bioclasts.

Intraclasts, peloids, granular aggregates, ooids, and sometimes extraclasts, are present together with bioclasts. The intergranular space is filled with fine sediment or cement. Three main types of microfacies were identified based on the association of these elements: oncoidic-bioclastic grainstone, bioclastic-peloidal grainstone and intraclastic-peloidal-bioclastic packstone (Pl. I, Fig. 5). These deposits are usually well sorted, and intercalated with the intertidal and supratidal facies.

These characteristics indicate environments with high hydrodynamic energy, under wave action. The micropaleontological assemblage is similar to the one described for the subtidal/lagoonal sub-environment. Some of the bioclastic bars show meteoric dissolution and reprecipitation structures.

The grain-supported type facies associations and the clast content point out to a normal marine environment, with shallow waters and high hydrodynamic energy. In this environment, deposits can accumulate as tidal and littoral bars in coastal areas (Ginsburg, 1975, Shinn, 1983a; Hardie and Shinn, 1986; Tucker and Wright 1990; Pratt et al., 1992).

b) *Intertidal sub-environment*

Some of the characteristics of the intertidal sub-environment are the predominance of intraclasts and peloids, scarce fauna and flora, micritization of bioclasts, and intraclasts, the presence of fenestral structures, bioturbations, and discontinuity surfaces (hardground) at a very small (millimetric) scale.

The most representative facies are intraclastic-bioclastic grainstone/packestone, peloidal packestone/grainstone and intraclastic-peloidal packestone/wackestone, all with fenestral structures (Pl. I, Fig. 6). Intraclasts, peloids and fenestral structures predominate. Some other elements like extraclasts (silt-size), ooids and bioclasts can be identified, and they usually have a micritic coating.

These deposits are moderate to well-sorted and they contain arenitic-sized carbonate clasts. Intraclasts consist of non-fossiliferous mudstone or wackestone with marine fauna, and can be rounded and subangular in shape, but sometimes elongated and flattened intraclasts are also present (Pl. I, Fig. 6). These facies contain ostracods, small thin-shelled gastropods, miliolids, and cyanobacteria. Bioclasts from normal marine environment (fragments of echinoids, bivalves, gastropods, foraminifera, dasycladacean algae) are generally dissolved or micritized. Between the clasts there is usually a micritic meniscus-type cement. The fenestral structures have millimetric size and flattened to spherical or irregular shapes. The hollow spaces can be filled with cement, geopetal-type internal sediment, or a combination of both, which highlights the influence of meteoric waters.

These moderate to well sorted deposits, consisting predominantly of arenitic-sized intraclasts and peloids (with flattened, elongated, rounded and subangular shapes) indicate an environment with more active hydrodynamics. The fenestral structures are characteristic features for upper intertidal to supratidal environments (Shinn, 1968; Lucia, 1972; Shinn, 1983a, b; Tucker and Wright, 1990).

In the same sub-environment we include some other types of limestones, like peloidal mudstone and peloidal-extraclastic wackestone with coprolites (Pl. I, Figs. 7, 8). These facies are interpreted as belonging to the lower intertidal environment, because an intensely bioturbated mixture of calcareous mud, pellets and bioclasts can be found only in these areas (Ginsburg, 1975; Shinn, 1983a; Hardie and Shinn, 1986; Tucker and Wright, 1990; Pratt et al., 1992). The observed bioturbations are very well defined (Pl. I, Fig. 7) and their infill contains peloids, bioclasts and extraclasts, elements that underline the proximity of coastal areas. These facies associations indicate an intertidal environment with low hydrodynamic energy.

c) *Supratidal sub-environment*

We assigned to this category all carbonate facies that show strong evidence of subaerial exposure and the facies represented by non-fossiliferous mudstone, sometimes laminated, or with laminar intercalations of fine peloidal packestone (Pl. III, Figs. 1-6). Fenestral peloidal mudstone/wackestone type limestones, with scarce fauna and flora, are interpreted as deposits of gradual transition of facies from intertidal to supratidal areas (Pl. III, Figs. 1, 2). Towards the top of the peloidal laminae, small (millimetric) and flattened fenestrae are aligned

horizontally. Large and irregular fenestrae develop inside the laminae or peloidal-bioclastic strata. The micritic laminae that appear as intercalations contain sometimes calcified cyanobacteria. These surfaces can be interpreted as small scale (millimetric) discontinuities (hardground?) (Pl. III, Fig. 2). The fenestral structures can be preserved in the upper intertidal area only if an early lithification of the sediment has occurred, and the fenestrae were filled with cement or internal sediment (Shinn, 1983a). Evidence for this is the presence of irregular fenestrae developed in the micritic facies with no bioturbation, showing that these deposits were protected from wave action.

Supratidal areas are indicated by extraclasts, the very restrictive flora and fauna, and fenestrae filled with vadose silt. Swamps or supratidal pounds can also appear in this area, and are represented by wackestone/mudstone with ostracods, small gastropods with thin shells, and cyanobacteria, which indicates a restrictive or isolated environment from the supratidal/coastal area (Pl. III, Fig. 6).

Fenestral structures are characteristic features of the upper intertidal-supratidal environments (Shinn, 1968; Lucia, 1972; Shinn, 1983a, b; Tucker and Wright, 1990). Cyclical changes of water depth is reflected by facies evolution at individual strata scale, showing a transition between subtidal, intertidal, and supratidal depositional environments (Pl. III, Fig. 5).

CRETACEOUS CARBONATE MICROFACIES AND FACIES

In the studied area, the contact between the Cretaceous and Jurassic limestones is probably tectonic (Figs. 1, 3). In other areas of the Bihor Mountains, the Cretaceous lies unconformably and transgressive over the Jurassic deposits (Dragastan et al., 1986). In the Pădurea Craiului Mountains, the Cretaceous follows a gap in sedimentation due to the regional uplift of the area during the Late Jurassic (Patrușiu, in Ianovici et al., 1976). Moreover, bauxitic deposits occur at the base of the Cretaceous sequence.

In the studied area, bauxitic deposits were found only in one location (Sohodoale Valley). The bauxitic rocks are reddish in color, stratified, and outcrop alongside with massive limestones. They contain boulders of Jurassic limestones, consisting of paleosols, lacustrine limestones and paleokarst filling.

Based on sedimentological and micropaleontological characteristics, the Cretaceous deposits that outcrop in the studied area were separated in two main types of facies associations (Pls. IV-V), from base to top: 1) peritidal/coastal facies, and 2) open shelf (offshore) facies with isolated bioconstructions and bioclastic banks. In many cases, the limestones are fractured and recrystallized making it difficult to determine the microfacies and micropaleontological association.

Peritidal/coastal facies

The limestones belonging to this depositional system are represented by peritidal deposits and are found in the basal to median part of the Cretaceous succession. Subtidal, intertidal and supratidal limestones have also been identified.

LATE JURASSIC		EARLY CRETACEOUS					
Kimmeridgian	Tithonian	Be	Vg	Hv	Barremian	Aptian	
							<i>Labyrinthina mirabilis</i>
							<i>Kurnubia palastiniensis</i>
							<i>Neokilianina rahonensis</i>
							<i>Parurgonina caelinensis</i>
							<i>Pseudocyclammina lituus</i>
							<i>Redmondoides lugeoni</i>
							<i>Mohlerina basiliensis</i>
							<i>Andersenolina alpina</i>
							<i>Evericyclammina hedbergi</i>
							<i>Pseudolituonella gavonensis</i>
							<i>Charentia cuvillieri</i>
							<i>Paracoskinolina? jourdanensis</i>
							<i>Montseciella arabica</i>
							<i>Palorbitolina lenticularis</i>
							<i>Sabaudia minuta</i>
							<i>Campbelliella striata</i>
							<i>Clypeina sulcata</i>
							<i>Salpingoporella annulata</i>
							<i>Salpingoporella pygmaea</i>
							<i>Falsolikanella danilovae</i>
							<i>Neomeris cretacea</i>
							<i>Salpingoporella melitae</i>
							<i>Salpingoporella muehlbergii</i>
							<i>Suppiluliumaella ellioti</i>
							<i>Thaumatoporella parvovesiculifera</i>
							<i>Marinella lugeoni</i>
							" <i>Solenopora</i> " sp.
							<i>Crescentiella morronensis</i>
							<i>Bacinella irregularis</i>
							<i>Lithocodium aggregatum</i>

Fig. 3. The most important species identified in the Upper Jurassic-Lower Cretaceous limestones from Hodobana-Gârda Seacă region, and their stratigraphical range.

The subtidal deposits are predominantly mudstone/wackestone type limestones, that contain rudists, corals, echinoids gastropods, bivalves, dasycladaleans, benthic foraminifera (orbitolinids and miliolids), rare ostracods, and rivulariacean-type cyanobacteria (Pl. IV, Fig. 1). These facies contain sometimes levels with low diversity of fauna and flora, with cyanobacteria and microproblematica (*Bacinella*-type structures), ostracods, small thin-shelled gastropods, and rare thin-shelled foraminifera, indicating a restrictive environment. In many cases, the normal marine subtidal deposits pass gradually to more restrictive conditions ("lagoonal"), emphasized by the in-situ encrustations of rudists by cyanobacteria and microproblematica (e.g., *Bacinella*) (Pl. IV, Fig. 2). Subtidal limestones formed in environments with high hydrodynamic energy are represented by coarse rudstone/grainstone and coarse bioclastic packestone (Pl. IV, Fig. 3). They contain diverse normal marine fauna and flora, represented by rudists, corals, echinoids, bivalves, gastropods, calcareous algae [*Marinella lugeoni* PFENDER (Pl. V, Fig. 1), "*Solenopora*" sp., *Falsolikanella danilovae* (RADOIČIĆ), ?*Linoporella* sp., *Salpingoporella melitae* RADOIČIĆ, *Salpingoporella muehlbergii* (LORENZ), *Salpingoporella pygmaea* (GÜMBEL) (Pl. V, Fig. 2), *Suppiluliumaella* sp. (Pl. V, Fig. 3), *Suppiluliumaella ellioti* BAKALOVA (Pl. V, Fig. 4), *Neomeris cretacea* STEINMANN (Pl. V, Fig. 5), *Neomeris* sp. (Pl. V, Fig. 6), and *Terquemella* sp.], foraminifera [miliolids, *Palorbitolina lenticularis*

(BLUMENBACH) (Pl. V, Fig. 7), *Montseciella arabica* (HENSON) (Pl. V, Fig. 8), *Paleodictyoconus* sp. (Pl. V, Fig. 9), *Paracoskinolina? jourdanensis* (FOURY & MOULLADE), *Mayncina* sp. (Pl. V, Fig. 10), *Evericyclammina* sp. (Pl. V, Fig. 11), *Evericyclammina hedbergi* (MAYNC) (Pl. V, Fig. 12), *Coscinophragma* sp., *Vercorsella* sp., *Charentia cuvillieri* NEUMAN, *Meandropsira* sp., *Nezzazatinella* sp. (Pl. V, Figs. 13, 14), *Pseudolituonella gavonensis* FOURY (Pl. V, Fig. 15), *Neotrocholina* sp., *Trocholina* sp., *Troglotella incrustans* WERNLI & FOOKES], and microproblematica (?*Carpathoporella* sp). The elements are predominantly bioclasts, intraclasts and peloids, with subangular to rounded shapes. In most of the cases, the upper part of these limestones shows evidence of vadose diagenesis (Pl. IV, Fig. 4). Besides the sin-depositional marine cement (isopachous acicular cement), stalactitic and meniscus cements can be seen. The meteoric water induced strong dissolution of bioclasts and sparitic cement, generating vuggy and moldic porosity. The new-formed spaces were afterwards filled with micritic sediment that contains ostracods, small thin-shelled gastropods, and microbialites, which indicates a restrictive or isolated environment (swamps or ponds in intertidal and supratidal areas) (Pl. IV, Fig. 4). These coarse deposits with normal marine fauna are interpreted as belonging to tidal or littoral bars from coastal areas.

A predominantly fenestral fabric characterizes the intertidal limestones. Their main facies are fenestral

peloidal-bioclasic wackestone/packestone (lower hydrodynamic energy) (Pl. IV, Fig. 5), and peloidal-bioclasic or peloidal-oidic grainstone (higher hydrodynamic energy of the environment) (Pl. IV, Fig. 6). Small-scale (millimetric) discontinuity surfaces (hardground) are visible in these deposits, as well as horizontal laminae and fenestral structures (flattened to

irregular shapes, disposed parallel to lamination). These deposits are frequently associated with facies from intertidal pounds or supratidal swamps. The intertidal environment is indicated by the fenestral fabric (keystone vugs type in granular facies) and the presence of rudist fragments, foraminifera (especially miliolids), gastropods, and rivulariacean-type cyanobacteria.

Fig. 4. a). Geological map of Gârda Seacă-Hodobana from Dimitrescu et al. (1977) and Bleahu et al. (1980); b). Geological map of the same area modified according to data in this study. Note the different extent of the Upper Jurassic limestones near the overthrust drawn along the Gârda Seacă Valley (see text for details). 1: Arieșeni Nappe; 2: Gârda Nappe; 3: Barremian-Lower Aptian undivided Urgonian type limestones; 4: Upper Jurassic biogenic reefs and oncoidic limestones; 5: Lower Jurassic conglomerates, sandstones, shales, marls, and limestones; 6: Ladinian-Lower Carnian Wetterstein type limestones; 7: Ladinian sandstones, shales, breccia, and limestones; 8: Anisian dolomites and Werfenian conglomerates, sandstones, and shales; 9: Metamorphic rocks; 10: Quaternary deposits; 11: Faults; 12: Thrust front; 13: Samples locations; 14: Uncertain cartographical limit for the Upper Jurassic limestones identified in this study.

The supratidal limestones are usually thin, millimetric to centimetric in thickness, and are represented by supratidal plain and swamp deposits (Pl. IV, Fig. 7). The most characteristic features of this environment are the laminated micrites with ostracods and algal-microbial mats. Brackish/lacustrine deposits are formed from bioclastic mudstone/wackestone with ostracods and thin-shelled molluscs (Pl. IV, Fig. 7). During the evolution of the carbonate platform, these limestones were subject to periods of subaerial exposure, highlighted by dissolution, stalactitic and meniscus cement, and facies with black pebbles, all typical for a vadose environment.

Open shelf (offshore) facies, with isolated bioconstructions and bioclastic banks

Towards the upper part of the peritidal succession, a gradual transition to subtidal open shelf (offshore) deposits can be observed. These limestones appear in the median to upper part of the Cretaceous succession. Marine and restrictive facies were identified, accumulated in environments with high hydrodynamic energy (bioclastic banks and coral bioconstructions) or low energy, in subtidal and outer shelf areas. The most representative facies are coral boundstone (Pl. IV, Fig. 8), Studia UBB Geologia, 2011, 56 (1), 11 – 27

packestone/wackestone with rudists, bioclastic grainstone/rudstone with rudists and bioclastic mudstone/wackestone. Bioclasts are represented by in-situ rudists, isolated corals, sponges, echinoids, large gastropods, large benthic foraminifera (orbitolinids), dasycladalean algae, and rivulariacean-type cyanobacteria.

The Cretaceous succession shows a progressive drowning of the shelf, indicated by the transition from peritidal to open, normal marine environment deposits.

MICROPALAEONTOLOGICAL ASSOCIATIONS AND BIOSTRATIGRAPHIC CONSIDERATIONS

Within the studied succession from Hodobana-Gârda Seacă region we identified micropaleontological associations characteristic for Kimmeridgian-Early Tithonian and Barremian-Early Aptian intervals.

The most important species identified and their stratigraphical range are listed in Fig. 3. For the Upper Jurassic limestones, the assemblage with *Labyrinthina mirabilis*, *Kurnubia palastiniensis*, *Neokilianina rahonensis*, and *Parurgonina caelinensis* is most indicative for the Kimmeridgian-Early Tithonian age (e.g., Bassoullet, 1997).

The Barremian-Early Aptian age limestones are documented by the orbitolinid foraminifera *Paracoskinolina? jourdanensis*, *Montseciella arabica*, *Palorbitolina lenticularis*, as well as the dasycladalean algae *Falsolikanella danilovae*, *Salpingoporella melitae*, *S. muehlbergii*, and *Suppiluliumaella elliotti* (e.g., Arnaud-Vanneau, 1980; Granier and Deloffre, 1993; Becker, 1999; Bucur, 1999).

We also emphasize on the fact that many samples collected from limestones credited as Middle Triassic or Lower Cretaceous on the geological map 1:50.000, proved to belong in fact to Upper Jurassic, so that certain cartographic changes are envisaged (Fig. 4).

DISCUSSIONS AND CONCLUSIONS

In the Hodobana-Gârda Seacă region, the Kimmeridgian-Thitonian limestones are outcropping on a larger area than it was known before. They are represented by bioconstructions, oncoidic limestones and their associated facies, characteristic for Valea Crișanului and Albioara formations (*sensu* Dragastan et al., 1986) or by deposits formed in marine subtidal environments with high hydrodynamic energy, and peritidal environments. They are covered by Barremian-Aptian limestones in a typical Urgonian facies, with organisms that generated bioclasts, most of them derived from rudists, corals, and sclerosponges. However, the coral-sponge bioconstructions are not important elements of the Urgonian limestones.

Field observations and data obtained from studies on thin sections and polished slabs indicate that extensive limestone areas in the Gârda Seacă-Hodobana region attributed on the 1:50.000 scale geological maps (sheets 56b-Poiana Horea and 56d-Avrăm Iancu; Bleahu et al., 1980; Dimitrescu et al., 1977) to Triassic (Ladinian-Lower Carnian) and Lower Cretaceous, belong in fact to the Upper Jurassic carbonate succession (Fig. 4). Taking into account that Bucur and Onac (2000) reached the same conclusion with respect to the limestones from Scărișoara Ice Cave (not far from Hodobana-Gârda region), a re-evaluation of the lithostratigraphic units on the two maps following microfacies-micropaleontological studies seems to be necessary.

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Plate I. Jurassic facies and microfacies. Polished slab (Fig. 1) and photomicrographs (Figs. 2-8). Scale bar is 1 cm in Fig. 1 and 1 mm in Figs. 2 to 8.

Fig. 1. Coral bioconstructions;

Fig. 2. Intraclastic-bioclastic grainstone-packestone, with echinoids, bryozoans and mollusc fragments, miliolids, *Crescentiella moronensis* (CRESCENTI), and reef-derived intraclasts;

Fig. 3. Bioturbated wackestone/packestone, with dasycladales [*ClYPEINA sulcata* (ALTH)] and foraminifera;

Fig. 4. Fenestral packestone, with rivulariacean-type cyanobacteria;

Fig. 5. Oncoidic-bioclastic grainstone, with bioclasts [mollusc fragments, foraminifera, dasycladales - *Campbelliella striata* (CAROZZI)] with micritic coatings, and oncoids formed entirely from rivulariacean-type cyanobacteria;

Fig. 6. Fenestral intraclastic-bioclastic grainstone, with intraclasts of different shapes (flattened, elongated, rounded and subangular);

Fig. 7. Peloidal packestone (in the lower part) in alternation with bioturbated peloidal mudstone (in the upper part);

Fig. 8. Peloidal wackestone with coprolites.

PLATE I

Plate II. Jurassic microfossils. Rhodophyta (Fig. 1), dasycladales (Figs. 2-5) and foraminifera (Figs. 6-11). Scale bar 1 mm in Fig. 1 and 0.5 mm in Figs. 2 to 11.

Fig. 1. „*Solenopora*” sp.;

Fig. 2. *Campbelliella striata* (CAROZZI);

Fig. 3. *Salpingoporella annulata* CAROZZI;

Fig. 4. *Salpingoporella pygmaea* (GÜMBEL);

Fig. 5. *Clypeina sulcata* (ALTH);

Fig. 6. *Labyrinthina mirabilis* WEYNSCHENK;

Figs. 7, 10. *Parurgonina caelinensis* CUVILLIER, FOURY & PIGNATTI MORANO;

Fig. 8. *Neokilianina rahonensis* (FOURY & VINCENT);

Fig. 9. ?*Everticyclammina* sp.;

Fig. 11. *Kurnubia palastiniensis* HENSON.

PLATE II

Plate III. Jurassic facies and microfacies. Photomicrographs. Scale bar is 1 mm.

Figs. 1, 2. Fenestral peloidal mudstone/wackestone, with calcified cyanobacteria; the fenestrae are horizontal and have flattened shapes;

Fig. 3. Extraclastic, non-fossiliferous mudstone; this facies shows evidences of dehydration (crack traces);

Fig. 4. Bioclastic wackestone, with gastropods and ostracods – subaerial exposure indicated by circumgranular, vertical and horizontal cracks;

Fig. 5. Graded transition (from base to top) from fenestral intraclastic-bioclastic grainstone (intertidal) to packestone with ostracods (supratidal swamps) and finally to non-fossiliferous intraclastic mudstone/wackestone (supratidal/coastal).

Fig. 6. Wackestone/mudstone with ostracods, small thin-shelled gastropods (swamps and supratidal pounds).

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PLATE III

Plate IV. Cretaceous facies and microfacies. Photomicrographs. Scale bar is 1 mm.

Fig. 1. Bioclastic packestone/wackestone, with rudist and echinoid fragments, foraminifera and dasycladalean algae;

Fig. 2. Bioclastic packestone, with in-situ rudists incrustated by cyanobacteria and microproblematica (*Bacinella*).

Fig. 3. Bioclastic-intraclastic rudstone, with corals, rudists, echinoids, and dasycladalean algae (*Suppiluliumaella elliotti* BAKALOVA).

Fig. 4. Subtidal limestone deposited in environments with high hydrodynamic energy, and subsequently subaerially exposed – it shows dissolutions, stalactitic and meniscus cement, and the intergranular spaces are filled with ostracod- and small thin-shelled gastropod-bearing micrite;

Fig. 5. Fenestral peloidal-bioclastic packestone;

Fig. 6. Fenestral peloidal-ooidic-bioclastic grainstone;

Fig. 7. Wackestone/mudstone with ostracods and small thin-shelled gastropods.

Fig. 8. Coral boundstone.

PLATE IV

Plate V. Photomicrographs of Cretaceous microfossils. Rhodophyta (Fig. 1), dasycladales (Figs. 2-6), and foraminifera (Figs. 7-15).

Scale bar 1 mm in Fig. 1 and 0.5 mm in Figs. 2 to 15.

Fig. 1. *Marinella lugeoni* PFENDER;

Fig. 2. *Salpingoporella pygmaea* (GÜMBEL);

Fig. 3. *Suppiluliumaella* sp.;

Fig. 4. *Suppiluliumaella elliotti* BAKALOVA;

Fig. 5. *Neomeris cretacea* STEINMANN;

Fig. 6. *Neomeris* sp.;

Fig. 7. *Palorbitolina lenticularis* (BLUMENBACH);

Fig. 8. *Montseciella arabica* (HENSON);

Fig. 9. *Paleodictyoconus* sp.;

Fig. 10. *Mayncina* sp.;

Fig. 11. *Everticyclammina* sp.;

Fig. 12. *Everticyclammina hedbergi* (MAYNC);

Figs. 13, 14. *Nezzazatinella* sp.;

Fig. 15. *Pseudolituonella gavonensis* FOURY.

PLATE V