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BIOLOGY AND GEOLOGY FACULTY
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Upper Jurassic – Lower Cretaceous limestones from Vâlcan Mountains: microfacies, microfossils and paleoenvoronmental reconstruction

~PhD Thesis Summary~

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INTRODUCTION

Research conducted in this paper targeted Upper Jurassic – Lower Cretaceous carbonate deposits from the southern border of Vâlcan Mountains. Micropaleontological, biostratigraphic and paleoenvironmental studies weere conducted. Such an approach was necessary in this area, where, in spite of the large number of previous regional geology studies on this area, there are only a few data regarding the biostratigraphy and lithology of the local sedimentary deposits. This is due to the scarcity of biostratigraphic markers within these deposits and to their recrystallization caused by late Senonian tectonics.

The present paper comprises the results of the geological study of a vast area from Vâlcan Mountains. During the research 13 geological sections were sampled from which more than 900 rock samples were collected and transformed into thin sections. The main limitatios were related to the bad outcrop conditions, not allowingus to continuously follow the stratigraphic succession and to perform a continuous sampling as well as the of diagenetic overprint, high degree of compaction and fracturing that obliterated the large scale sedimentary structures and stratification. The study aims to describe the facies and microfacies, to reconstruct the paleoenvironments and their evolution in time, and to bring some new biostratigraphical data.

CHAPTER 1
LOCATION AND GEOGRAPHYC SETTING

The Vâlcan Mountains are located in the Southern Carpathians between the Jiu Valley (to the east), the Petroșani Basin (to the north), the Motru Valley (to the west) and the Getic Depression (to the south). The Upper Jurassic—Lower Cretaceous limestones crop out on the southern border of the Vâlcan Mountains and they were studied in stratigraphic sectionsalong the Cheii, Pocuia, Sudoieșului, Valea lui Mareș, Cireșului, Albului, Pârgavului, Bistrița, Sârbului – Sohodol, Bota, and Motru Sec Valleys (Fig. 1).

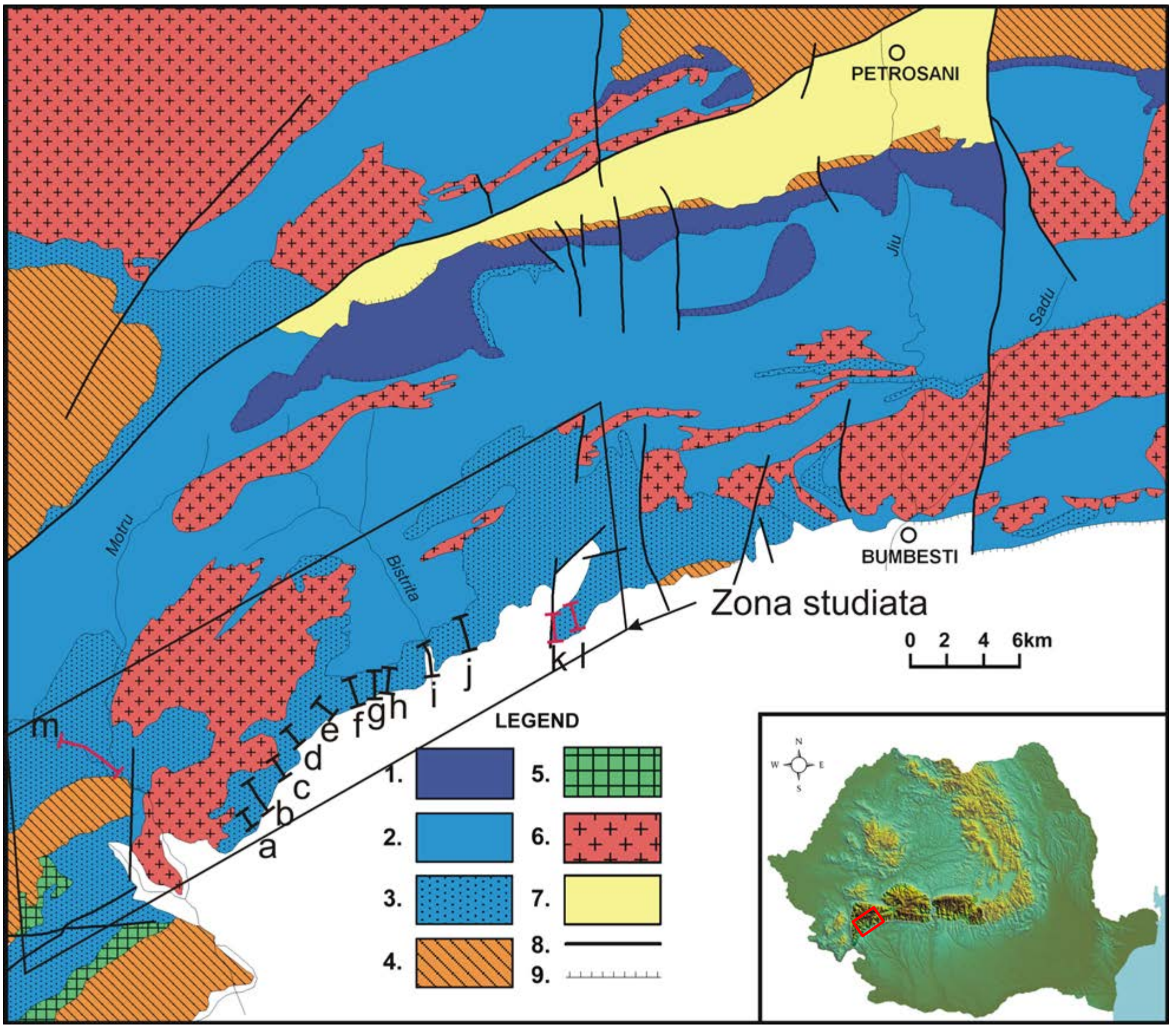

Fig 1. Location of the studied area (simplified map after Berza et al. 19941 – Upper Danubian Nappes, 2 – Lower Danubian Nappes, 3 – Jurassic—Cretaceous cover, 4 – Getic Nappe, 5 – Severin Nappe, 6 – Pre-Alpine granitoids, 7 – Cenozoic basins, 8 – Fault, 9 – Overthrust. **a—m** – studied sections: a – Costeni, b – Cheii, c – Pocuia, d – Sudoiesului, e – Valea lui Mares, f – Pârgavului, g – Albului, h – Ciresului, i – Bistrita, j – Sârbului, k – Sohodol, l – Bota, m – Motru Sec.

CHAPTER 2
GEOLOGICAL RESEARCH HISTORY FROM THE CERNA – JIU AREA

Researches related strictly to the area of Vâlcan Mountains are scarce, most papers are related to regional geology and comprise vaster areas. Therefore, the area that is subject of this chapter is located in the SW sector of Southern Carpathians comprising Vâlcan Mountains, Mehedinți Mountains and Mehedinți Plateau.

2.1 CONTRIBUTIONS TO THE TECTONICS OF THE WESTERN PART OF SOUTH CARPATHIANS

Over time several authors have proposed different tectonic models for the region in question, name, number, stratigraphy and areal extension of the Nappes differ from one author to another.

As early as 1904, Mrazec revealed the contact between the two groups of cristaline rocks and assigned them to two different domains (Getic and Danubian). Following the tectonic relations between the two groups and between crystalline and sedimentary cover, Murgoci (1905) identified the overthrust of the Getic domain over the Danubian domain as a large overthrust nape. Streckeisen (1934) validated the model and separated another tectonic unit on top of the Getic Nape, called ”the Superior Napes”.

Codarcea (1940) recognizes an autochthonous crystalline toghether with its Messozoic sedimentary cover (Danubian Autochthonous) being covered by the Severin Nape, followed by the Getic Napes. Most geologists who conducted further studies in the South Carpathians accepted, in big lines, the tectonic scheme developed by Codarcea.

Following multiple studies published by Berza et al., (1983, 1986, 1988a, b, 1989), related to smaller areas, the synthesis of all the tectonic units of the Danubian Domain was presented by Balintoni et al. (1989), and improved by Berza et al. (1994a).

Berza et al. (1994b) presented a simplified version of the Danubian Napes as exemplified in figure 2.

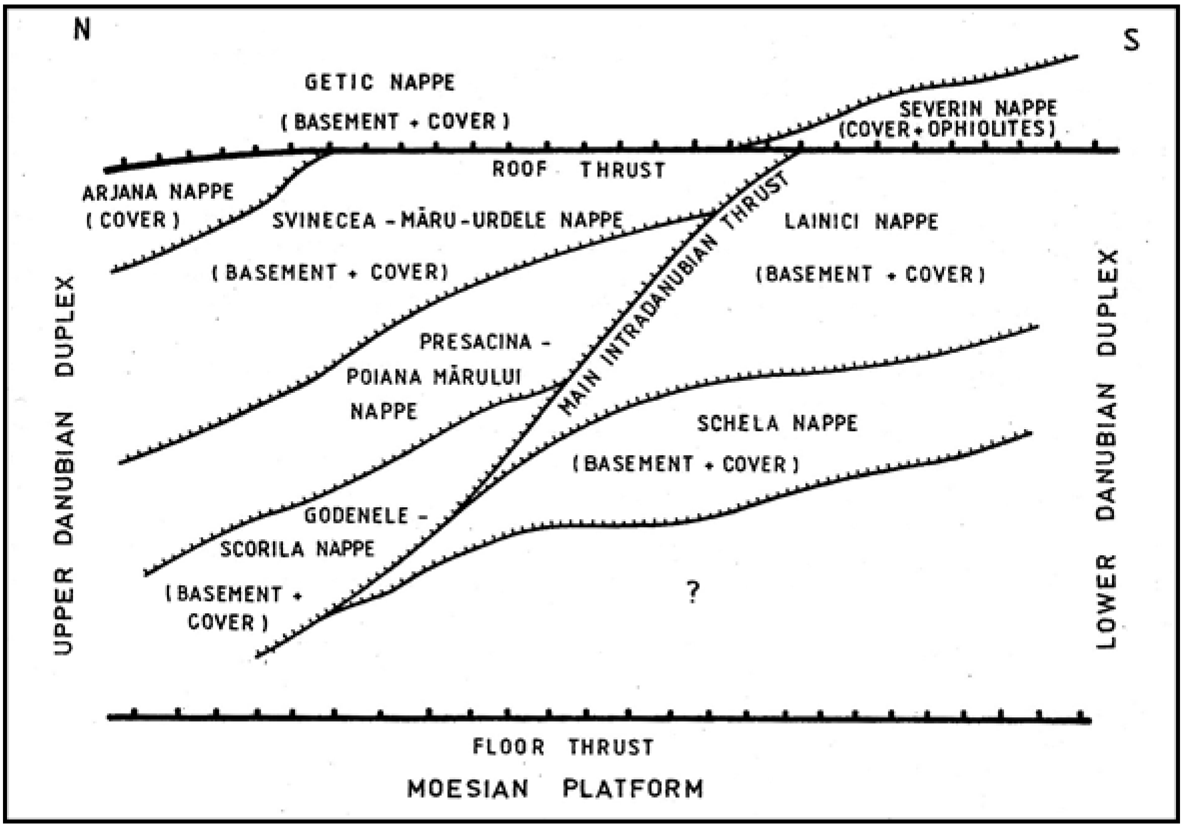

Fig. 2 Danubian Nape system (from Berza et al., **1994b**).

Balintoni (1997), used the term Danubian Euxinides for the Danubian Domain. In his acception they derived from the shear of the NW border of the euxinic plate during the Laramic tectogenesis, therefore synchronous with „the second getic fase" in Codarecea's (1940) acception.

Synthesizing the existing data, Balintoni (1997) described the following succession (from top to bottom)

Sintetizând datele existente, Balintoni (1997), a distins în cadrul Euxinidelor danubiene, următoarea succesiune (de sus în jos) (Fig. 3):

1. Arjana Nape
2. Dubova Nape
3. Svinecea–Măru–Urdele Nape
4. Presacina–Poiana Mărului Nape
5. Godenele–Scorila Nape
6. Băile Herculane Nape

7. Lainici Nape
8. Schela–Petreanu Nape.

Compared with Berza et al. (1994a) model, Balintoni includes two more napes: Dubova and Baile Herculane.

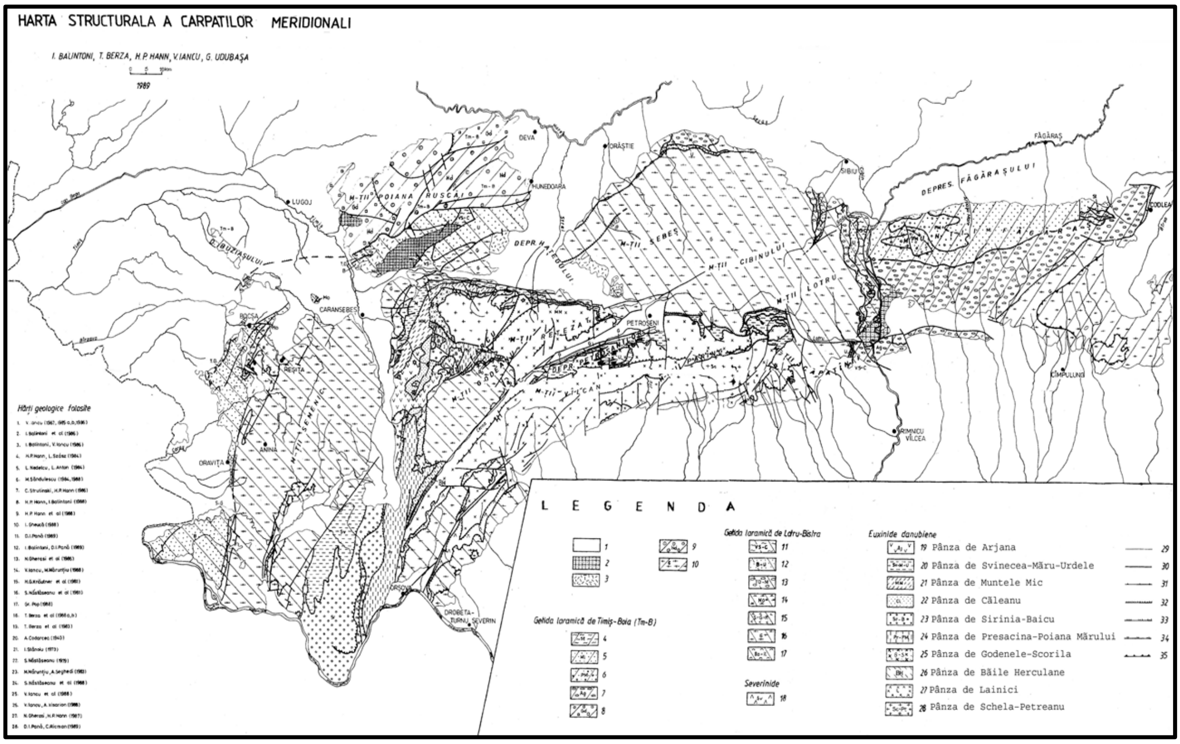

Fig. 3. South Carpathians structural map (from Balintoni ei al., 1997)

2.2 CONTRIBUTIONS TO THE STRATIGRAPY OF THE MESOZOIC DEPOSITS

In the Cerna – Jiu area due to the scarcity of paleontological evidences, the age of some rock complexes was assigned only by correlation with other Messozoic deposits from the nearby regions or simply by their spatial distribution. Among the contributions to the stratigraphy of this area we can mention Mrazec (1898), Murgoci (1916), Streckeisen (1931), Manolescu (1932, 1937), Codarcea (1940) or Mercus (1959).

The stratigraphy and geological structure of the Danubian sedimentary system from Vâlcan Mountains was approched by Mutihac (1964). The author separated two sedimentary cycles:

- First includes only the Schela Formation

- The second comprises Carboniferous, Permian, Jurassic and Cretaceous.

One of the most important contributions regarding the Mesozoic sedimentary deposits from Vâlcan Mountains was related to Pop. The author published several articles related with this matter (1965, 1966, 1967), followed by a book in 1973. The sedimentary succesion identified by Pop (1973) is presented in Fig. 4.

The last study in this area was made by Pop & Bucur in 2001. The authors have described four shallow water formations and a siliciclastic one. Bucur (în Pop & Bucur, 2001 mentioned that all the “formations” presented by them, as well as those introduced by Stănoiu et al. (1997) are *nomina nuda* because they don’t have a formal description (type locality, limits, lithologic description etc.). The 5 formations described by the authors are:

- Valea Pragurilor Formation (Oxfordian)
- Valea Cheii Formation (Oxfordian terminal - Kimmeridgian inferior)
- Topeşti Formation (Kimmeridgian-Tithonian)
- Nocomian deposits
- Izvarna Formation (Barremian - Apţian).

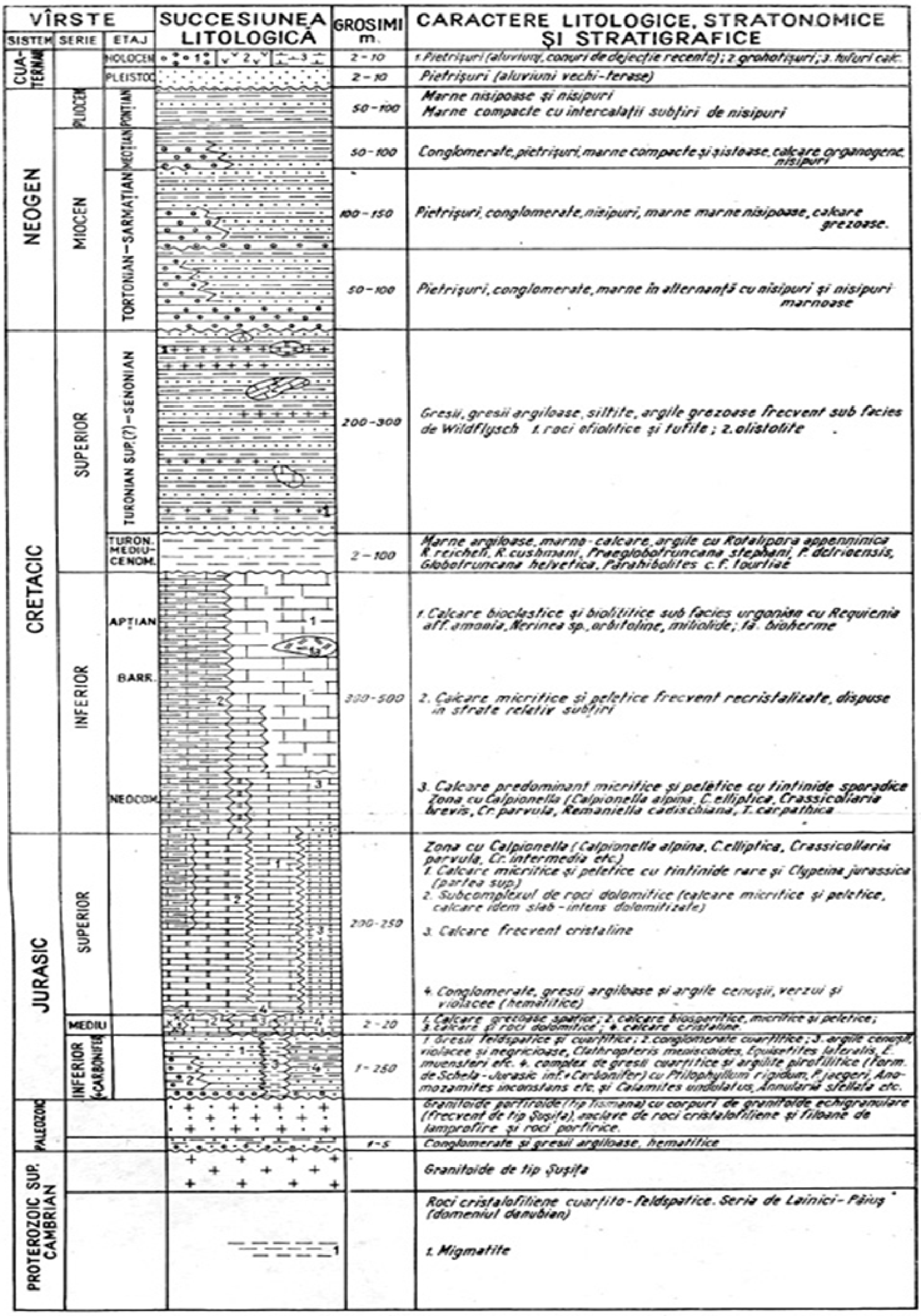

Fig. 4 Stratigraphic and lithological succession of the Mesozoic deposits (from Pop, 1973).

CHAPTER 3
GEOLOGY OF THE STUDIED REGION

The structure of the western part of the Southern Carpathians is represented by three groups of tectonic units. The lowermost unit is the Danubian Nappes, also called Danubian Euxinides (Balintoni 1997), the Danubian Domain or Danubian Autochthonous. This unit is overlain by the Severin Nappe, representing the suture between the Danubian Nappes and the Getic Nappe, which is the uppermost unit.

Except for some thin strips belonging to the Getic Nappe, the Vâlcan Mountains are dominated by the crystalline and volcanic rocks of the Lower Danubian Nappes (Berza et al. 1983), and by their Mesozoic cover (Fig. 5). The Mesozoic deposits belong to the sedimentary cover of the Lainici Nappe (Berza in Balintoni et al. 1989). The succession of the Mesozoic deposits in the area starts with Liassic deposits in Gresten-type Facies, followed by carbonate deposits of variable thickness (1—20 m), Middle Jurassic in age. The Upper Jurassic is represented by three formations: the Valea Pragurilor Formation (Oxfordian) – a calcarenitic sequence, often consisting of dolosparites; the Valea Cheii Formation (Upper Oxfordian—Lower Kimmeridgian) – a siliciclastic formation with regressive character (1—20 m thick); and the Topești Formation (Kimmeridgian—Tithonian) – consisting of shallow-water carbonate deposits dominated by blackish, fine to coarse stratified calcarenites and calcilutites. On the top of the Upper Jurassic deposits, a 40 m thick Neocomian limestone succession crops out. The Izvarna Formation (Barremian—Aptian) is the last carbonate formation developed in this region and it consists of Urgonian limestones, followed transgressively, and sometimes unconformably, by Upper Cretaceous clayey marls, marly-limestones and clays (Pop 1973; Pop & Bucur 2001).

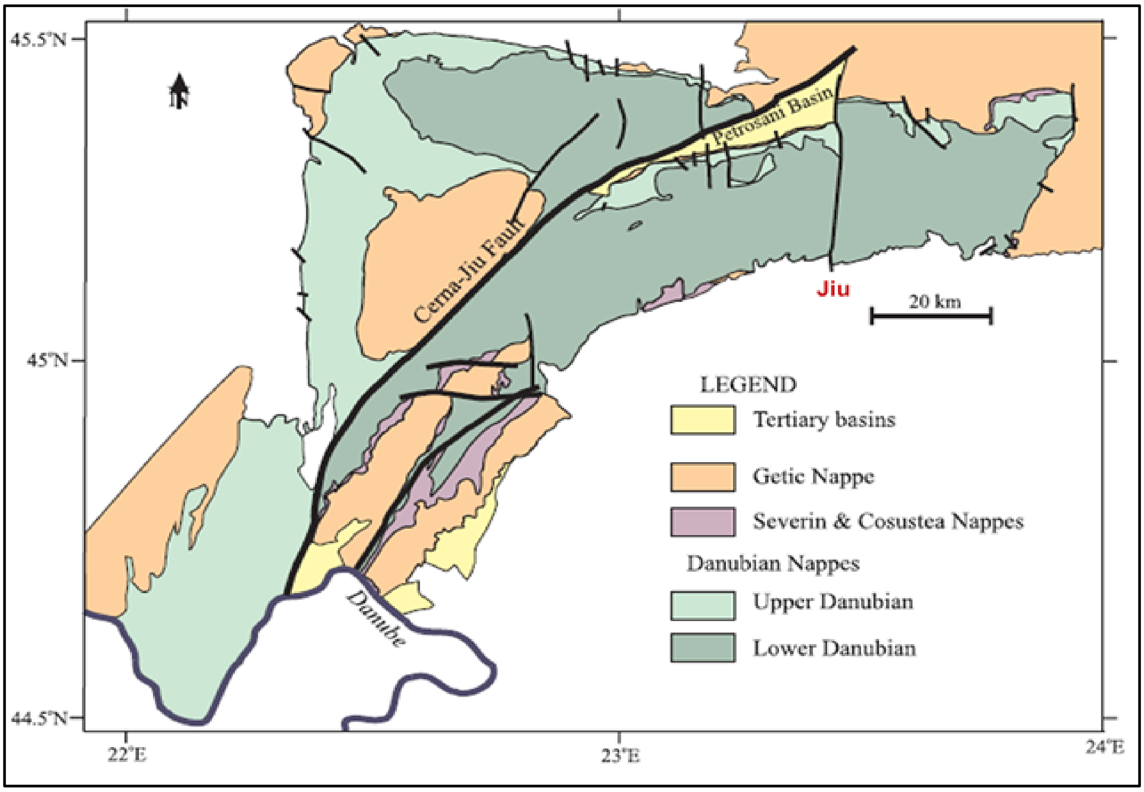

Fig. 5. The main tectonic units (after Seghedi et al., 2005)

CHAPTER 4
METHODOLOGY

The micrfaciesal study comprised a field-work stage and a laboratory stage.

4.1 Field-work stage

During this stage more than 900 rock samples have been collected from the 13 geologicla sections studied. All the samples were transformed into thin sections in the laboratory.

4.2 Laboratory work

The rock composition and fabrics requires thin sections with thickness of about 30 microns. All the samples were processed in the laboratory by specific methods.

Microscopic analysis

Thin section analysis was performed with a Zeiss Axioscop microscope and an Optika binocular. The microphotographs were taken with a digital camera attached to the microscope.

In the laboratory proper investigation tools were selected in order to meet the desired results. The main aspects observed during the microscopic study are related with matrix analysis and the qualitative and semi-quantitative analysis of the components that can give us information related with the controlling factors of the paleosedimentary environments.

Microfacies classification

The most commonly used classifications are the ones proposed by Folk (1959) & Dunham (1962) with additions from Embry & Klovan (1972). In this paper I mainly used the classification of Dunham (1962).

Microfacies interpretation

Microfacisurilor assessment in the context of facies interpretation requires a centralization of microfacies data observed in different samples into microfacies types TMF (Flügel, 2004). Microfacies types were defined in this paper by those criteria whose existence and abundance is determined by environmental factors that are specific and related to certain depositional settings. In defining these types of microfacies (TMF) I followed primary sedimentary structures and textures, early diagenetic features and biotic component.

For assigning microfacies types to a certain depositional paleoenvironment or subenvironment we have used both comparisons with existing carbonate deposits as well as other studies that targeted older carbonate platforms.

CHAPTER 5

MICROFACIES AND MICROFOSSILS OF THE STUDIED LIMESTONES

The Upper Jurassic – Lower Cretaceous limestones from Vâlcan Mountains were studied in stratigraphic sections along the Cheii, Pocuia, Sudoieșului, Valea lui Mareș, Cireșului, Albului, Pârgavului, Bistrița, Sârbului – Sohodol, Bota, and Motru Sec Valleys (Fig. 1).

The limestones from Motru Sec, Cheile Sohodolului și Bota have been strongly affected by digenesis, to the limit with metamorphism, and all the primary depositional structures and textures have been obliterated beyond recognition (Fig. 6).

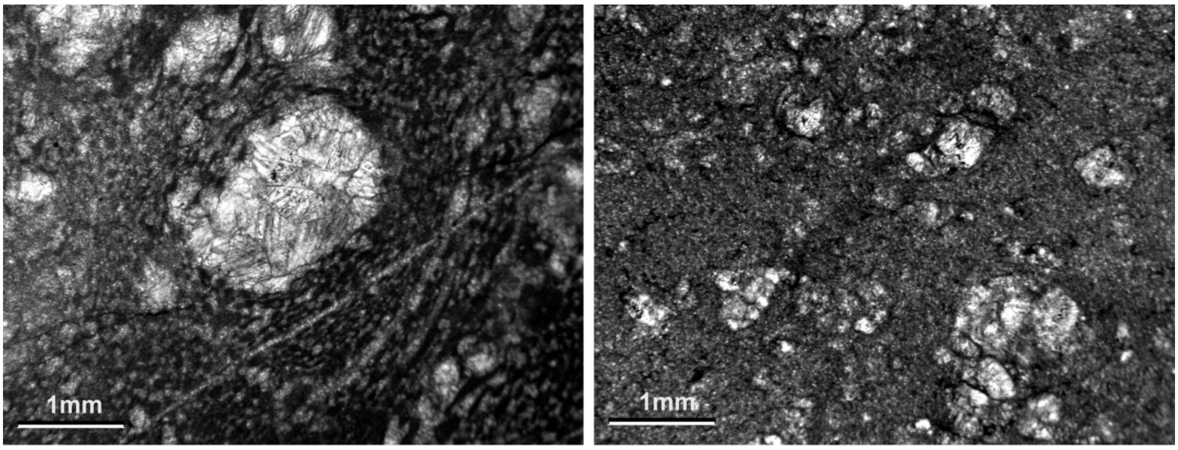

Fig 6. Recristalized limestones from Cheile Sohodolului.

The microfacies identified on the other sections can be separated into six microfacies types. Each MFT and its occurrence is described and the environmental interpretation is discussed.

MFT 1: non-fossiliferous, fenestral, laminated mudstone/wackestone and subaerial exposure facies

This facies type is scarcely represented in the stratigraphic succession, being more frequent in the lower part. The most typical diagnostic features of this facies type are represented by the presence of non-fossiliferous (or poorly fossiliferous) muds that gave birth to some unstructured or finely-laminated, fine granular micrites, sometimes including cryptomicrobial structures or rivulariacean-type cyanobacteria. Scattered dolomite rhombs are sometimes present in the micritic matrix and grains. Sometimes the whole structure is obliterated by mosaics of euhedral to subhedral dolomite crystals. Biodiversity is very low, microfossils being mainly represented by ostracods, rare foraminifers and gastropods. Charophyte fragments (stems and gyrogonite) are also locally present in a homogenous or fenestral matrix. Some reworked bioclasts from the subtidal area may also be present.

Also included in this facies association are sediments that undergone subaerial exposure. Exposure features include desiccated muds, paleosols and paleokarst. They are more common in the lower parts of the profiles from Sârbului and Bistriţa Valleys.

Interpretation. The non-fossiliferous, finely laminated muds and cryptalgal fabrics are common constituents of the supratidal environments with low energy gradients. On the other hand such deposits can also form in the upper intertidal zone. In these areas the fluctuating salinity and frequent exposures do not permit the existence and proliferation of infaunas or browsing organisms that churn and homogenize these primary sedimentary structures (Shinn, 1983). The presence of charophyte remains are usually regarded as good indicators of freshwater environments (Tucker & Wright, 1990), but salinity tolerant forms were also reported from recent and ancient brackish environments (e.g. Burne et al., 1980; Feist & Grambast-Fessard, 1984; Climent-Domènech & Martín-Closas, 2009). In the studied area the charophyte remains appear along with a brackish fauna with ostracodes, and sometimes are impregnated with Fe-oxides.

The most diagnostic criteria for supratidal environments are: evidence of subaerial exposure and pedogenic influence; and evidence of cementation in the vadose zone (Flügel, 2004). Evidence of pedogenic influence such as desiccation-brecciation, mottling, glaebule development, black pebbles, root structures and microkarst (Esteban & Klappa, 1983; James & Choquette, 1984; Demicco & Hardie, 1994), are all common features of this facies association.

The in situ brecciation of muds has led to the formation of polygonal fracture networks filled with sparite or with sediment containing peloids and pisoids. Brecciation is induced by desiccation, displacive crystallization of calcite, root activity and/or dissolution (Flügel, 2004). Carbonate nodules (or glaebules in soil terminology, see Esteban & Klappa, 1983) are also frequent constituents of caliche profiles, but their origins are not fully understood (Wright & Tucker, 1991). Circum-granular cracks, filled with spar cement, usually develop around glaebules. They are formed by alternate shrinkage and expansion induced by seasonal drying/wetting cycles (Esteban & Klappa, 1983). Mottling from red-brown, yellow to gray is also present. This is also a pedogenetic process that may develop as a result of fluctuating Eh – pH conditions or through redistribution of iron oxide, hydroxide particles (Buurman, 1980). The presence of black pebbles 'floating' in this type of matrix is probably related to the burning of organic matter, because features like the gradation of blackening and the angular nature of pebbles , seen here, are arguments cited by Shinn and Lidz (1988) as characteristic of subaerial fire blackening. Other interpretations include input of organic matter from the continent (Strasser, 1984) or the formation of finely disseminated pyrite (Wright, 1986a)

No rhizolite type crusts have been encountered, but some structures possessing alveolar-septal fabric were found. Similar structures have been reported by several authors from ancient and recent paleosols (Adams, 1980; Klappa, 1980; Wright, 1986b; Wright et al., 1988). They have been interpreted by Wright (1986b) as fungal activity around roots. Root traces represented by rounded or irregular voids lined with dense micritic coatings and interpreted as being the products of void lining biofilms or calcitic cutans (MacNeil & Jones, 2006) are also pedogenic indicators.

Microkarstic products represented by collapse breccias, solution voids, and sometimes speleotems (flowstone structures) are also present. Such structures seem to be superficial and might represent the products of the infiltration zone (upper vadose) (Esteban & Klappa, 1983).

MFT 2: fenestral wackestone/packstone-grainstone

This MFT is interlayered at different levels within the whole stratigraphic succession and is characteristic for the intertidal environment. One of the main features of these deposits is represented by the presence of fenestral structures. The fenestrae are millimetre in size and their shapes are flat to spherical or irregular. They contain sparitic cement, geopetal infillings, or are filled with vadose silt, pointing to a meteoric water influence. Other characteristic features of the intertidal regime are erosion alternating with deposition, as well as rapid changes in current and wave velocity (Ginsburg, 1975). Based on the structural and textural features, two subtypes have been separated: a) fenestral-laminated peloidal wackestone (formed in low hydrodynamic conditions) and b) fenestral peloidal packstone-grainstone (formed when the hydrodynamic conditions were at their peak).

a) The first type is commonly associated with microbial bindstones and wackestones formed in pool areas of the inter- and supratidal zone. The biodiversity is still low; sometimes inside the fenestrae one can find Charophyta oogones, probably reworked. Girogonites are easily transported, especially if they are desiccated (Wright, 1990). Small gastropods are sometimes present in the cyanobacterial mats (Fig. 5.4). Sometimes intensely burrowed muds, containing many Favreina type coprolites and rare ostracodes, are grading into fenestral microbial mats. The fenestrae associated with this subfacies are of laminoid-fenestral and irregular type.

b) These deposits are moderate- to well-sorted, sometimes displaying bimodal sorting; the particles are represented by well-sorted and well-rounded peloids, micritic intraclasts and oncoids. Bioclasts are relatively rare, they are represented by foraminifers [miliolids, textulariids, Sabaudia minuta (HOFKER) Vercorsella sp.] sometimes showing a micritic envelope, bivalves, recrystallized gastropods, algae, or Rivularia-type cyanobacteria. The fenestral pores within these deposits are of spherical to irregular types, keystone vugs being also locally present.

Interpretation. As many authors mentioned (e.g. Tucker & Wright, 1990; Flügel, 2004) the assignment of ancient limestones to the intertidal environment is a difficult task. This is due to the lack of reliable diagnostic features, and to the similarities with the adjacent environments. Fenestral structures in ancient and recent carbonate deposits are usually regarded as good indicators of upper intertidal to supratidal settings (Shinn, 1983; Tucker & Wright, 1990). Shinn and Robbin (1983) showed that open fenestrae are destroyed by mechanical compaction so that the preservation of fenestrae of all types in mudstones signifies that the host sediments were cemented before even shallow burial. Such an early cementation is a characteristic feature of peritidal deposits (James & Choquette, 1984; Grover & Read, 1978; Tucker & Wright, 1990; Shinn, 1983) Fenestrae have polygenic origins and may be caused by wetting and drying of carbonate mud, degassing of decaying organic material, drying out of the surface of cyanobacterial mats (in case of laminoid and irregular fenestrae), air and gas bubbles trapped during deposition of the host sediment or generated by post-depositional decay of organic matter (in case of spherical fenestrae) (Demicco & Hardie, 1994). Keystone vugs present in the grain supported facies are probably the result of air-bubble trapping during storm deposition in the squash zone on beaches or on the sheetwash zone on tidal flats (Shinn 1986; Demicco & Hardie, 1994; Flügel, 2004). Irregular fenestrae associated with cyanobacterial mats can be the result of irregular growth of this mats (Săsăran, 2006).

Fenestral limestones containing abundant fenestrae, associated with distinctive early diagenetic features (crystal silt, leached fossils, micritization of bioclasts originating from normal marine environments), erosional surfaces, cryptalgal sediments, and a restricted biota (ostracods and gastropods) suggesting periodic emergence and desiccation, point to an intertidal environment of formation in the case of these deposits.

MFT 3: peloidal bioclastic packstone/grainstone

These limestone types are interlayered at several levels within the stratigraphic succession. The granular facies mainly consists of moderate- to well-sorted peloids with subangular to rounded morphologies, besides rare superficial ooids, micritic intraclasts and oncoids. Micritised bioclasts are common. Skeletal grains appear in various quantities and are represented by gastropods, fragments of bivalves and echinoderms, benthic foraminifera [Kurnubia palastiniensis HENSON, Protopeneroplis striata WEYSCHENK, Andrersenolina cherchiae (ARNAUD-VANNEAU & BOISSEAU), Mohlerina basiliensis (MOHLER), Paracoskinolina? jourdanensis (FOURY & MOULLADE), Pseudocyclammina lituus YOKOYAMA, Sabaudia minuta (HOFKER), Vercorsella sp.] dasycladalean algae (Clypeina parasolkani FARINACCI &

RADOIČIĆ, Pseudoactinoporella fragilis CONRAD, Salpingoporella sp.), and cyanobacteria nodules (of Rivularia-type).

Interpretation. The non-skeletal components, such as peloids, intraclasts, ooids, cortoids and oncoids, and mostly sparitic, or at least partly sparitic groundmass are indicating an agitated subtidal environment. The diverse skeletal components, such as larger and smaller benthic foraminifera and calcareous algae point to normal marine, well-oxygenated conditions. These deposits were formed in shallow subtidal environments above the fair weather wave base.

MFT 4: packstone-grainstone with rudists and wackestone/packstone with algae and foraminifera

These deposits, characteristic of the middle and upper part of the section, consist of wackestone/packstone, and packstone-grainstone with highly diversified paleontological assemblages: molluscs, benthic foraminifera, and green algae. At certain intervals, rudists took part to the colonization of the substrate building-up a typical Urgonian type facies. The rudists characterizing this facies have a patchy distribution, thick shells, large sizes and they show no signs of perforation, micritisation or encrustation. The sediment associated to this facies is usually represented by poorly washed packstone-grainstone with small and very diverse foraminifera (especially miliolids, cuneolinids and textulariids) and peloids.

Another facies, associated with the rudistid one, is represented by wackestone-packstone with algae and large benthic foraminifera. The main characteristic of this facies is the diversification of organisms in mud-supported, sometimes bioturbated matrix. Dasycladalean green algae are very frequent [Clypeina solkani CONRAD & RADOIČIĆ, Salpingoporella melite RADOIČIĆ, Salpingoporella muehlbergii (LORENZ), Similiclypeina conradi BUCUR], along with benthic foraminifera [Montseciella arabica (HENSON), Neotrocholina friburgensis GUILLAUME & REICHEL, Vercorsella scarsellai (DE CASTRO)] and other skeletal grains similar to those of the high energy environment.

Interpretation. The Lower Cretaceous rudists are usually regarded as characteristic inhabitants of very shallow waters (infralittoral) and are especially linked to the inner, more or less protected parts of the Urgonian platforms (Masse, 1976, 1979, 1992; Masse & Philip, 1981; Skelton & Gili, 1991). Also their association with a grainy-muddy substrate containing abundant small foraminifera suggests inner platform (lagoonal) conditions with moderate to low energy conditions.

The intensely bioturbated bioclastic wackestone microfacies types containing normal marine fauna dominated by dasycladalean algae besides foraminifers with complex tests, rudist fragments, and gastropods have been interpreted as being formed in the lower subtidal environment with low hydrodynamics. The presence of dasycaladacean green algae points to warm relatively shallow waters (Bucur & Săsăran, 2005).

Sometimes, the deposits corresponding to the microfacies types 3 and 4 show traces of subaerial exposure, such as dissolution and recrystallization of bioclasts, or voids filled with vadose-type siltic sediment.

MFT 5: wackestone/packstone with rudist fragments and microencrusters, and packstone-grainstone with cyanobacteria

This MFT is associated to the subtidal marine facies presented above and it is represented by peloidal wackestone/packstone with abundant microencrusters and bioclastic packstone-grainstone with cyanobacteria. The diversity of flora and fauna is low, bioclasts being mainly represented by microproblematic microencrusters of Bacinella (very abundant) or Lithocodium type and rivulariacean-type cyanobacteria. Bacinella is present either in the matrix of these deposits, or inside and around the bioclastic fragments forming oncoids. The bioclastic fragments are mainly represented by bored and micritised rudist fragments and never contain whole rudist shells. The sediment is inhomogeneous, suggesting intensive burrowing.

Sometimes, these deposits may contain a normal marine fauna with foraminifers, algae, echinids or rudists, associated to peloids and intraclasts. This association witnesses an original normal marine environment later grading into a restrictive one, a change leading to the colonization of the substrate by calcimicrobial structures and finally even to the subaerial exposure of the sediment, with related dissolution, reprecipitation and micritization processes affecting the bioclasts.

Interpretation. This association is characterized by the presence of Bacinella and Lithocodium along with fragmented rudist shells. The systematic position of Bacinella and Lithocodium was intensely disputed; the first one being usually interpreted as a cyanobacteria (Schäffer & Senowbari-Daryan, 1983; Maurin et al., 1985; Camoin & Maurin, 1988) while the second one was regarded as a Codiacean algae, lituolid foraminifera, or cyanobacteria (for a comparison of different taxonomic interpretations see Schlagintweit et al., 2010). Recently Schlagintweit et al. (2010) re-interpreted these organisms as being ulvophycean green algae.

Regardless of their taxonomic position most authors regarded the two microproblematic organisms as being characteristic for very shallow, well-oxygenated and relatively oligotrophic environments (Leinfelder et al., 1993; Dupraz & Strasser, 1999, 2002; Pittet et al., 2002; Reolid et al., 2009). The absence or scarcity of other marine biota is also consistent with this interpretation. Besides encrustation, borings, breakage, burrowing and micritisation are common, indicating low accumulation rates (Enos, 1983). This facies was formed in a shallow subtidal environment with restrictive circulation.

MFT 6: bioclastic packstone/ grainstone (bioclastic shoals)

This facies dominates the upper part of the succession. The most typical carbonate particles included are bioclasts, represented by echinoderm plates (sometimes consisting more than 50 % of the total) of arenitic sizes and recrystallized fragments of molluscs. Most bioclasts are coated; they either exhibit constructive micritic envelopes, or are marginally or completely micritised. Besides, well-rounded to subangular peloids, micritic intraclasts, cyanobacterial nodules, foraminifera [Montseciella arabica (HENSON), Palorbitolina sp., Palaeodyctioconus actinostoma ARNAUD-VANNEAU], and dasycladalean algae are present. The echinid fragments are well-rounded and sometimes show syntaxial overgrowth cement. Some bioclasts show clear traces of subaerial exposure: processes of micritization, dissolution and recrystallization under the effect of meteoric waters.

Interpretation. These deposits showing evidence of intense reworking, subaerial exposure and containing a predominantly open marine biota suggests their formation in a marine environment with high hydrodynamics; they represent bioclastic shoals from the platform margin area (corresponding to FZ 6 sensu Wilson, 1975 and Flügel, 2004). This microfacies is sometimes passing into wackestones and packstones containing angular bioclastic fragments and representing the perishoal offshore environment.

CHAPTER 6
BIOSTRATIGRAPHIC CONSIDERATION

The studied deposits were assigned to the Upper Jurassic–Lower Cretaceous (Oxfordian–Barremian) with some uncertainties regarding the Hauterivian deposits which were not documented paleontologically (Fig.7).

The Upper Jurassic age was based on foraminifera : Alveosepta jaccardi (SCHRODT), Parurgonina caelinensis CUVILLIER, FOURY & PIGNATTI MORANO, Kurnubia palastiniensis HENSON, Protopeneroplis striata WEYSCHENK, Neokilianina sp., Verneuilina sp., and several dasycladalean algae: Megaporella boulangeri DELOFFRE & BEUN, Clypeina sulcata (ALTH), and Salpingoporlla annulata CAROZZI.

Among the foraminifera, the most significant species is Alveosepta jaccardi. It was first described by Schrodt (1894, as Cyclammina jaccardi) from Upper Oxfordian–Middle Kimmeridgian deposits in Switzerland. It was subsequently reported from Upper Oxfordian–Lower Kimmeridgian formations (Pelissié & Peybernès, 1982; Cociuba, 1997; Pop & Bucur, 2001). Septfontaine (1981) proposed an A. jaccardi Biozone, ranging from Middle Oxfordian to Early Kimmeridgian. The species was also described from Kimmmeridgian rocks (Altiner, 1991; Omaña & Arreola, 2008).

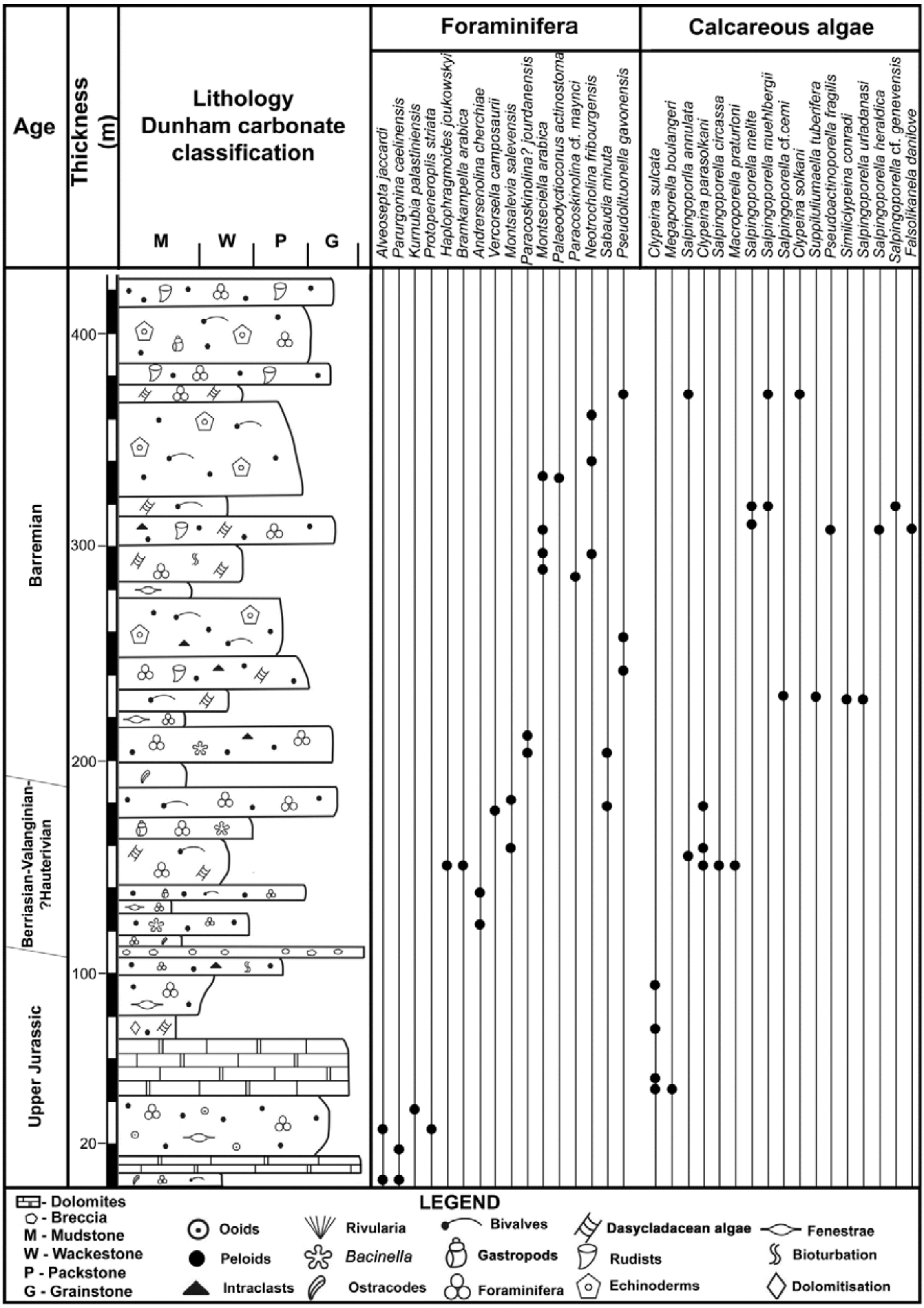

Figure 7. General succession of the carbonate deposits from Vâlcan Mountains, with vertical distribution of the identified marker microfossils.

Parurgonina caelinensis was first described from Kimmeridgian–Portlandian formations by Cuvillier et al. (1968). The species was placed either in the Lower Kimmeridgian (Pelissié et al., 1984; Tasli, 1993), the Kimmeridgian–Lower Tithonian (Pop & Bucur, 2001; Velić, 2007, Bucur & Săsăran, 2005), or the Oxfordian–Middle Tithonian (Bassoullet, 1997a).

Kurnubia palastiniensis is another typical foraminifer for Upper Jurassic deposits. It was found in Lower Oxfordian (Pelissié & Peybernès, 1982), Oxfordian–Kimmeridgian (Peybernès, 1976; Clark & Boudagher-Fadel, 2002), Kimmeridgian (Hottinger, 1967; Altiner, 1991; Omaña & Arreola, 2008), Kimmeridgian–Lower Tithonian (Pop & Bucur, 2001; Schlagintweit et al., 2005) or in Oxfordian–Middle Tithonian (Bassoullet, 1997a; Bucur & Săsăran, 2005; Velić, 2007) formations. To summarise, the distribution interval for this species is Oxfordian–Middle Tithonian.

The same time interval is indicated by the calcareous algae assemblage. Megaporella boulangeri was described from the Kimmeridgian of Morocco (Deloffre & Beun, 1986). Recently, Bouaouda et al. (2009) revised the distribution of this alga in the Marocan Atlantic basin; he assigned it to the Callovian–Oxfordian interval. In the Tethysian area, the species was identified by Pop & Bucur (2001) in Kimmeridgian– Tithonian deposits from the South Carpathians, Romania. Clypeina sulcata is typical for the Kimmeridgian–Berriasian interval (Granier & Deloffre, 1993; Bassoulet, 1997b; Bucur, 1999).

In the Berriasian–Valangian–?Hauterivian deposits, a micropaleontological association consisting of foraminifers: Haplophragmoides joukowskyi (CHAROLLAIS, BROENNIMANN & ZANINETTI), Andrersenolina cherchiae (ARNAUD-VANNEAU, BOISSEAU & DARSAC), Montsalevia salevensis (CHAROLLAIS, BROENNIMANN & ZANINETTI), Bramkampella arabica REDMOND, Vercorsella camposaurii (SARTONI & CRESCENTI), Mohlerina basiliensis (MOHLER), Mayncina sp., and calcareous algae: Clypeina parasolkani FARINACCI & RADOIČIĆ, Clypeina sp., Salpingoporella circassa (FARINACCI & RADOIČIĆ), Salpingoporella annulata CAROZZI, and Macroporella praturloni DRAGASTAN has been identified.

Andersenolina cherchiae has been frequently reported from Berriasian–Valanginian deposits (Arnaud-Vanneau, 1980; Neagu, 1994; Bucur et al., 1995; Mancinelli & Coccia, 1999; Pop & Bucur, 2001). Velić (2007) considered H.

joukowskyi, M. salevensis and V. camposaurii to be index fossils for the Valanginian of the Adriatic carbonate platform.

The Barremian–Aptian foraminiferal association consists of the following species: Paracoskinolina? jourdanensis (FOURY & MOULLADE), Montseciella arabica (HENSON), Orbitolinopsis sp.?, Paracoskinolina sp.?, Paracoskinolina cf. maynci (CHEVALIER), cf. Palaeodictyoconus actinostoma ARNAUD-VANNEAU & SCHROEDER, ? Palorbitolina sp., Vercorsella scarsellai (DE CASTRO), Everticyclammina hedbergi (MAYNC), Pseudolituonella gavonensis (FOURY), Debarina hahounerensis (FOURCADE, ROUL, VILA), Neotrocholina friburgensis GUILLAUME & REICHEL, Sabaudia minuta (HOFKER), Pseudocyclammina lituus YOKOYAMA, (c'est bien cette espèce?) Nautiloculina broennimanni ARNAUD-VANNEAU & PEYBERNES, Everticyclamina sp., Vercorsella sp., Nautiloculina sp., Charentia sp. and Commaliama sp. The association of calcareous algae includes: Salpingoporella muehlbergii (LORENZ), Salpingoporella melite RADOIČIĆ, Salpingoporella cf. cemi RADOICIC, Salpingoporella sp., Clypeina solkani CONRAD & RADOIČIĆ, Clypeina cf. solkani (CONRAD & RADOIČIĆ), Suppiluliumaella tuberifera (SOKAĆ & NIKLER), Milanovicella sp. and Clypeina sp., Pseudoactinoporella fragilis CONRAD, Similiclypeina conradi BUCUR, Salpingoporella cf. genevensis (CONRAD), Salpingoporella heraldica SOKAĆ, Salpingoporella urladanasi CONRAD & PEYBERNES, and Falsolikanella danilovae (RADOIČIĆ).

As a whole, this association is characteristic for the Barremian interval in the Mesogean area. Among the species in this association, the most important biostratigraphically are the orbitolinids such as Paracoskinolina? jourdanensis. It represents clear paleontological evidence for the presence of Lower Barremian in the studied limestone succession (Michetiuc et al., 2008). Also the orbitolinids Paracoskinolina cf. maynci and cf. Palaeodictyoconus actinostoma, encountered in the upper part of the succession from Sârbului Valley, have been identified in the interval between the upper part of Lower Barremian to the Lower Aptian (Masse, 1976; Arnaud-Vanneau, 1980; Bucur, 1997). Clavel et al. (2010) revised the biostratigraphic distribution of the orbitolinids by correlation with ammonite zonations placing the first occurrence of Paracoskinolina maynci in the Upper Hauterivian and that of the Palaeodictyoconus actinostoma in the

Lowermost Barremian. The calcareous algae assemblage characterizes the Barremian–Aptian time interval (Granier & Deloffre, 1993; Bucur, 1999).

CHAPTER 7
PALEOENVIRONMENTAL RECONSTRUCTION AND EVOLUTION

The detailed microfacies study allows the differentiation of several facies belts. In a transect from platform to basin the following facies zones occurs: (1) inner platform, (2) middle platform and (3) outer platform (Fig.8). For a better understanding of depositional facies belts, comparisons with modern settings have been used.

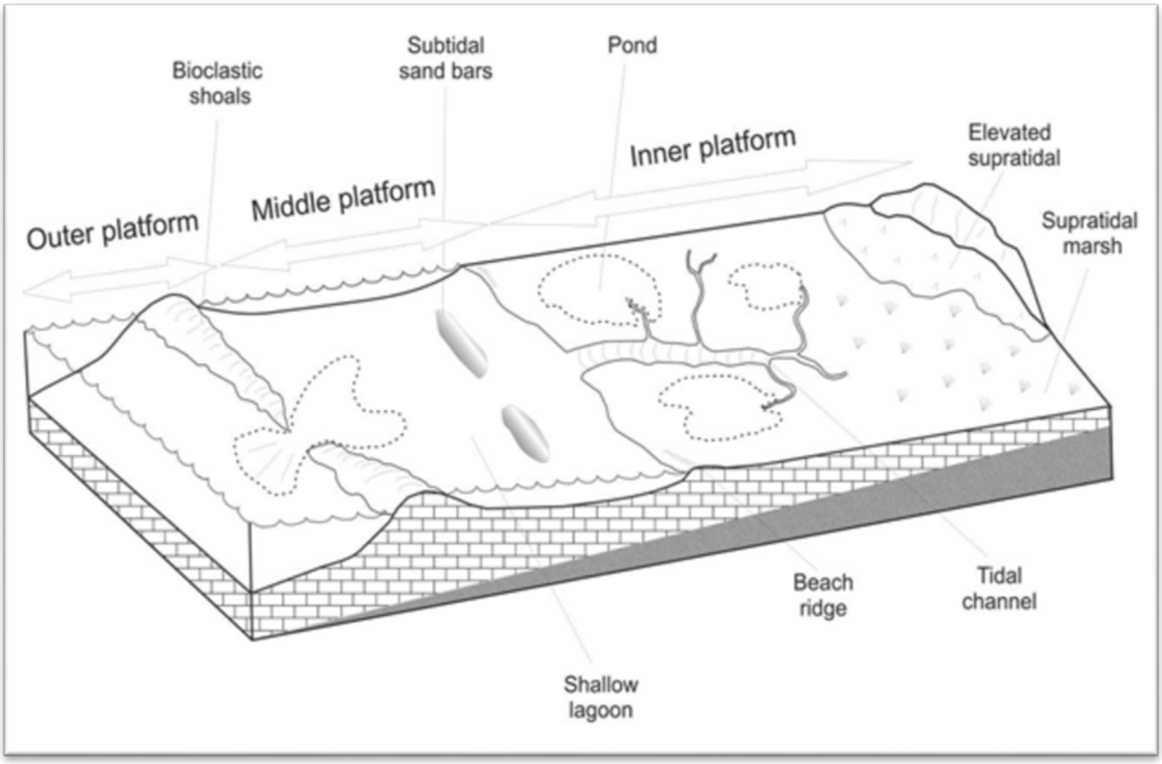

Figure 8. Schematic reconstruction of the distribution of paleoenvironments of the Vâlcan carbonate platform.

1. Inner platform. In most of the studied sections the peritidal deposits are dominating their lower parts, although some thin intercalations exist in the whole section (Fig. 9). The supratidal facies belt was dominated by finely crystalline, nonfossiliferous muds (MFT 1) representing the result of sedimentation on the vast, protected supratidal marshes that were subject to periodic flooding by sea water during spring tides and storm events. The presence of charophyte remains in some of these supratidal deposits suggests periods of freshwater input.

No well developed caliche profile or karstic features have been encountered in this deposits, but some evidence of subaerial exposure and pedogenesis do exist. In contrast, the supratidal deposits from the lower part of Sârbului section show grater thickness, no marine influence and more pronounced pedogenic features. These types of deposits were defined by MacNeil & Jones (2006) “disconnected palustrine deposits”. The local presence of such deposits suggests lateral facies variability, probably caused by the inherited paleotopography. A modern example of such deposits is the Florida Everglades showing that the climate and topography were important controls of the marginal marine settings (e.g. Platt & Wright, 1992).

The supratidal environments are good indicators of climatic conditions, and without having any mineralogical data, by virtue of sedimentological and early diagenetic data (lack of evaporites, paleosoil characteristics, meteoric water input) humid to sub-humid climatic conditions, similar to those of the modern Andros Island, can be assumed.

As already mentioned, recognition of intertidal facies belt and its subenvironments in ancient carbonates is a difficult task. Based on the energy of the environment we separated a low energy and a high energy subenvironment. The first one contain cryptalgal fabrics associated with laminar-fenestral or irregular fenestral fabrics (MFT 2a). They contain a restricted biota and were deposited on the ponded intertidal flats. In recent intertidal environments, situated especially in more humid climates, ponds are a very common feature (Pratt et al., 1992). The presence of abundant crustacean coprolites and burrows and their association with microbialites are also indicative for intertidal environments. In recent environments burrows by fiddler crabs are abundant in the lower intertidal flats and subtidal ponds (Shinn, 1983, 1986).

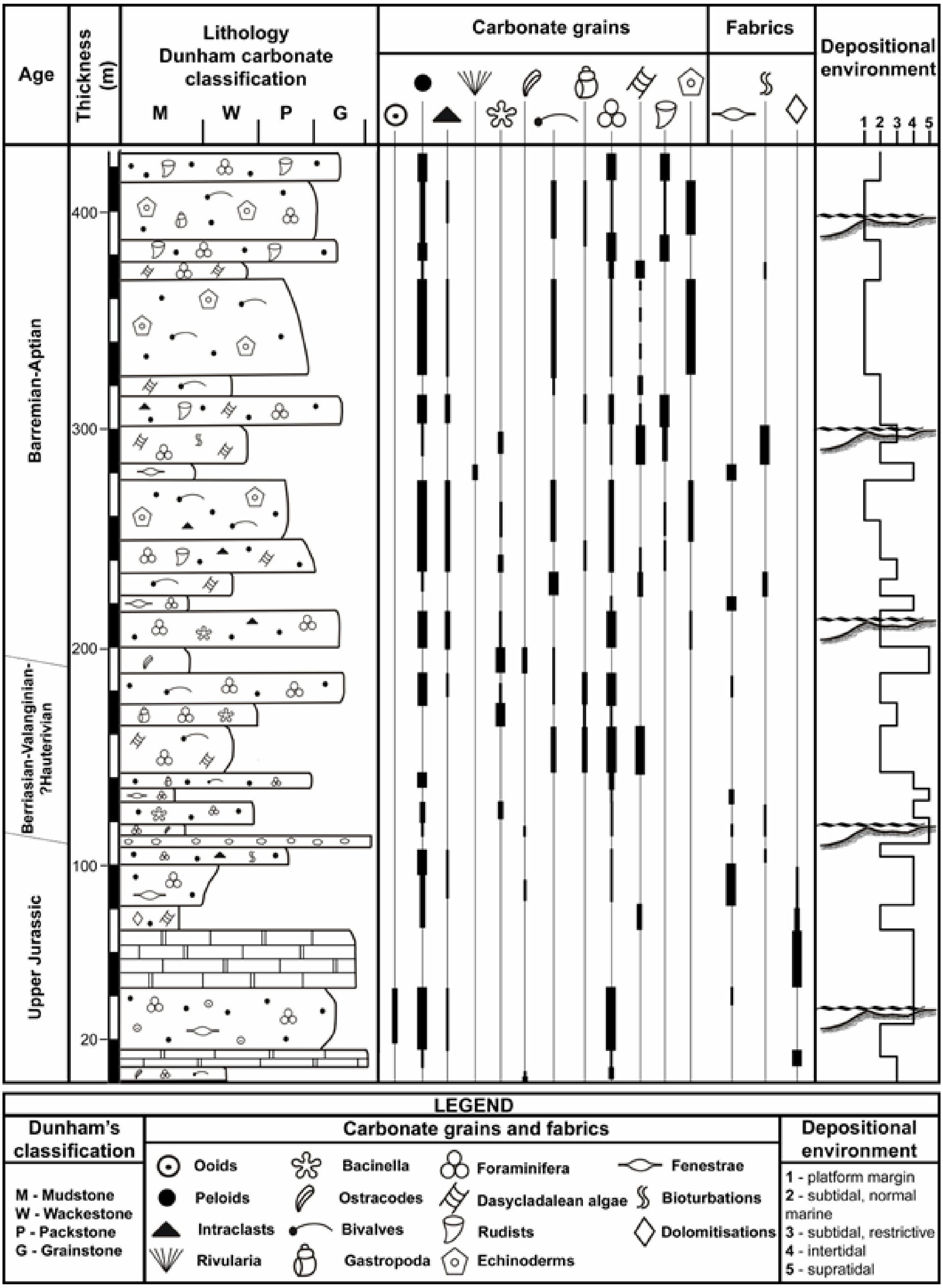

Fig. 9 General succession of the limestone deposits from Vâlcan Mountains (sintethic sections) (From Michetiuc et al., 2012).

The granular subfacies (MFT 2b) contain light gray intraclasts and rounded peloids, suggesting reworking of an early lithified sediment from the tidal flats.

Some of them may represent high energy events affecting the flats, while those containing keystone vugs might represent poorly developed beach ridges generated offshore of the tidal flats in the zone of breaking waves. Bimodal sorting is also a characteristic of beach foreshores or beach storm layers (Taira & Scholle, 1979).

The peritidal deposits could not be individualized into cycles because the complex succession of tidal flat subenvironments may rather register lateral migration of these subenvironments than a smooth vertical shallowing or deepening up.

2. Middle platform. The winnowed packstones and grainstones (MFT 3) rich in peloids, cortoids and intraclasts, containing different amounts of reworked benthic foraminifera and green algae, reflects deposition under high energy conditions. Moderate turbulence is indicated by high packing density, good sorting and roundness of particles (Bauer et al., 2002). They represent subtidal sand bars moved by bottom currents. In some cases, especially in the lower parts of the sections, were they are associated with intertidal deposits, they might represent tidal channel infillings. Unfortunately, the presence of tidal channels can only be assumed because bipolar (heringbone) cross stratification is not present, probably because of intense bioturbation or strong diagenesis affecting the limestones.

The low energy subtidal environments (MFT 4) are dominating the middle-upper parts of the sections and were deposited in protected or semi-protected parts of the platform. The protection was ensured by the bioclastic shoals from the platform margin (see discussion below). The ecological requirements of microfauna (especially benthic foraminifera and green algae) suggest shallow marine environment. The same ecological significance was inferred to the rudists assemblages, which were compared (Masse, 1976; Masse et al., 2003) with the Pinna–Pinctada assemblages thriving in shallow waters of the Shark Bay or the Arabian-Persian Gulf. Such shallow water environments were very sensitive to bathymetric changes that can either open or isolate the carbonate platform.

These middle platform deposits show a shallowing upward trend. At one end of the spectrum are the mud dominated algal, foraminiferal wackestone-packstones, representing the deeper, protected environments of the photic zone. They are followed by packstone-grainstone with small foraminifera, associated with rudists, representing shallower and more energetic environments. The lack of micritisation, borings and encrustation on rudists shells suggests high depositional rates. High primary productivity is also sustained by the abundance of small foraminifers, which are considered to be R-mode opportunists that proliferate in nutrient-rich, ephemeral or stressed habitats (Fugagnoli, 2004). At the upper part of the cycle are deposits containing rudist fragments and microencrusters (MFT 5). Judging by the abundance of Bacinella and the lack of other marine biota (except rudist fragments) this facies represent the shallowest and more restricted environment. Intensive burrowing, perforations and micritisation suggest lower sedimentary rates. The fragmentation of rudists is probably the result of intensive in situ bioerosion (Gili, 1992; Gili et al., 1995) or of periodic reworking by high energy episodes.

Sometimes the cycles are caped by thin fenestral wackestones and mudstones of the intertidal zone. The superimposed meteoric diagenesis (grain dissolution, recrystalization, vadose silt) especially affected the MFT 5 and to some extend the MFT 4, suggesting subaerial exposures at the end of the cycles.

3. Outer platform. The great thickness of the deposits, predominance of echinoderm fragments along with other stenohaline organisms and the early diagenetic features, suggest the existence of some bioclastic shoals situated at the platform margin. These shoals were probably the main cause of platform restriction. The closest recent counterpart is represented by the offshore banks of Great Bahama Bank. Even though this facies was encountered only in the Upper Barremian, the existence of a high energy barrier at the platform margin before this period can be inferred from the prevailing restricted conditions. Likewise, in a section situated westward of the studied zone (Mehedinţi Plateau), belonging to the same limestone formation, we encountered a Tithonian–Berrasian offshore reef barrier represented by coral-microbial boundstones.

The shallowing up trend is still maintaining in the upper part of section, with the high energy shoals covering the normal marine and\or restrictive marine facies.

CHAPTER 8
CONCLUSIONS

The carbonate deposits from Vâlcan Mountains have been analyzed from a sedimentological and biostratigraphic point of view; lithofacies types, fossil assemblages, and their vertical distributions have been defined.

We have identified several microfacies types (MFT) within these successions, based on biotic and abiotic components, sedimentary structures and textures, and early diagenetic features having an environmental significance. The deposits are characteristic for a shallow carbonate platform and can be further subdivided into an inner, middle, and outer platform.

The inner platform deposits are represented by tidal flat deposits and were best developed during the Upper Jurassic. Deposition on the tidal flats occurred in a great variety of low and high energy subenvironments represented by supratidal marshes and disconnected palustrine deposits, intertidal flats, ponds, channels and beaches. They reflect tropical humid to sub-humid climatic conditions.

These deposits were followed by predominantly middle platform deposits, developed during the Lower Cretaceous. They were deposited in high energy environments and low energy environments formed in protected or semi-protected shallow subtidal environments. Rudists and small benthic foraminifera were the main sediment producers during the Urgonian high deposition rates.

The middle platform deposits interfinger, in the upper parts of the sections, with the outer platform deposits represented by high energy bioclastic shoals and their associated open marine deposits.

The vertical succession of microfacies reflects cyclic changes in water depth. They are more visible in successions from middle and outer platform where they are arranged in shallowing up cycles. These cycles are superimposed on an overall transgressive trend, testified by the predominance of the inner platform facies in the Upper Jurassic and the transition to middle and outer platform facies during the Lower Cretaceous.

Following the micropaleontologic study new biostratigraphic arguments have been added, completing and improving the few data available. Three associations of algae and foraminifera have been separated. The first association is characteristic for the Upper Jurassic, the second points to Berriasian–Valanginian (possibly also Hauterivian) age, while the third one is indicating the Barremian interval. The identified micropaleontological assemblages can also serve for comparisons with other Tethyan regions containing Upper Jurassic–Lower Cretaceous deposits.

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