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Upper Jurassic – Lower Cretaceous limestones from the Buila-Vânturarița Massif.

- Summary of the PhD thesis-

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C O N T E N T S

Keywords: Upper Jurassic – Lower Cretaceous, microfacies, biostratigraphy, diagenesis, encrusting micro-organisms, microbial structures, Southern Carpathians.

INTRODUCTION

This paper is the result of three years of doctoral training in order to complete a comprehensive study of the Upper Jurassic - Lower Cretaceous limestones of the Buila - Vânturariţa Massif (Vâlcea County).

During the Upper Jurassic - Lower Cretaceous, in some areas of the Southern Carpathians, such as Buila-Vânturarița Massif, massive reef limestone developed containing a wide variety of microbial crusts associated with various types of encrusting microorganisms. The main objectives of this paper are related to microfacies analysis. They were made in order to achieve a general overview of the genesis and evolution of the Mesozoic carbonate rimmed platforms of the Intra-Tethyan domain. Identification and interpretation of facies and microfossils associations, diagenesis processes or depositional paleoenvironment, marks the main objectives of this work. This study also aims to highlight the importance of microbial structures and encrusting microorganisms in stabilizing the reef frameworks within these carbonate deposits.

CHAPTER 1. Genereal overview on the Buila-Vânturariţa Massif.

The Buila-Vânturariţa Massif is located in the north-central part of Valcea County, part of the Căpăţânii Mountains, located in the central-southern part of the Southern Carpathians (Fig. 1). The lithological constitution, evolution and geomorphological features, offers an individuality to the Buila-Vânturariţa Massif in relation to the main chain of the Căpăţânii Mountains.

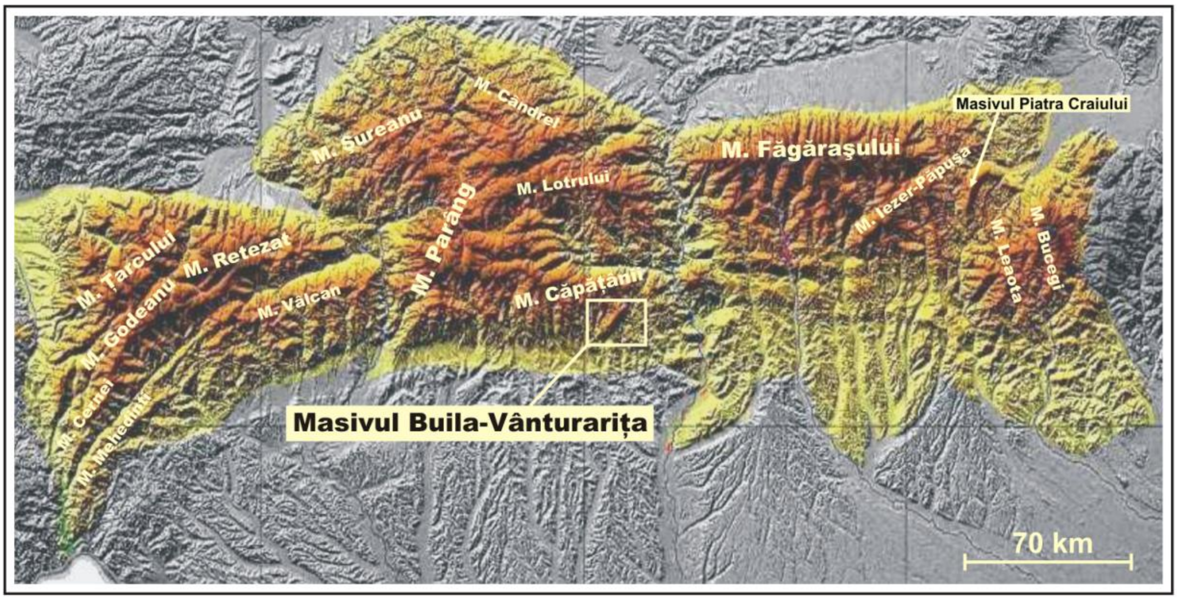

Fig. 1 – Location of the Buila-Vânturariţa Massif within the Southern Carpathians.

The Buila-Vânturariţa Massif represents a limestone ridge (consisting mainly of Jurassic limestones) with linear aspect, having a length of about 12 km and a width between 0.5 and 2 km. This massif is an important geological unit between the crystalline of Căpăţânii Mountains and the post tectonic sedimentary from this region (**Badea, 1998**). Limits are given by Bistrita Gorges (south-west) and Olănești Gorges (north-east).

The Buila-Vânturariţa Massif is actually a suspended syncline flank crossed by a series of transverse faults, calcareous deposits having an south to southeast inclination. They also extend between 800 and 1885 meters absolute altitude, the contact with crystalline formations being at a significant rate due to the dislocation and division of the deposits. The contact is mostly masked by the accumulation of debris present especially in the southwestern frame of the massif. Bistrita and Costești river valleys, pierce the calcareous deposits of the main ridge, thus separating two segments (Arnota and Stogu).

The morphology of the Buila-Vânturariţa ridge is similar to that of other massifs from the Carpathian arc, like Piatra Craiului Massif or Trascău Mountains.

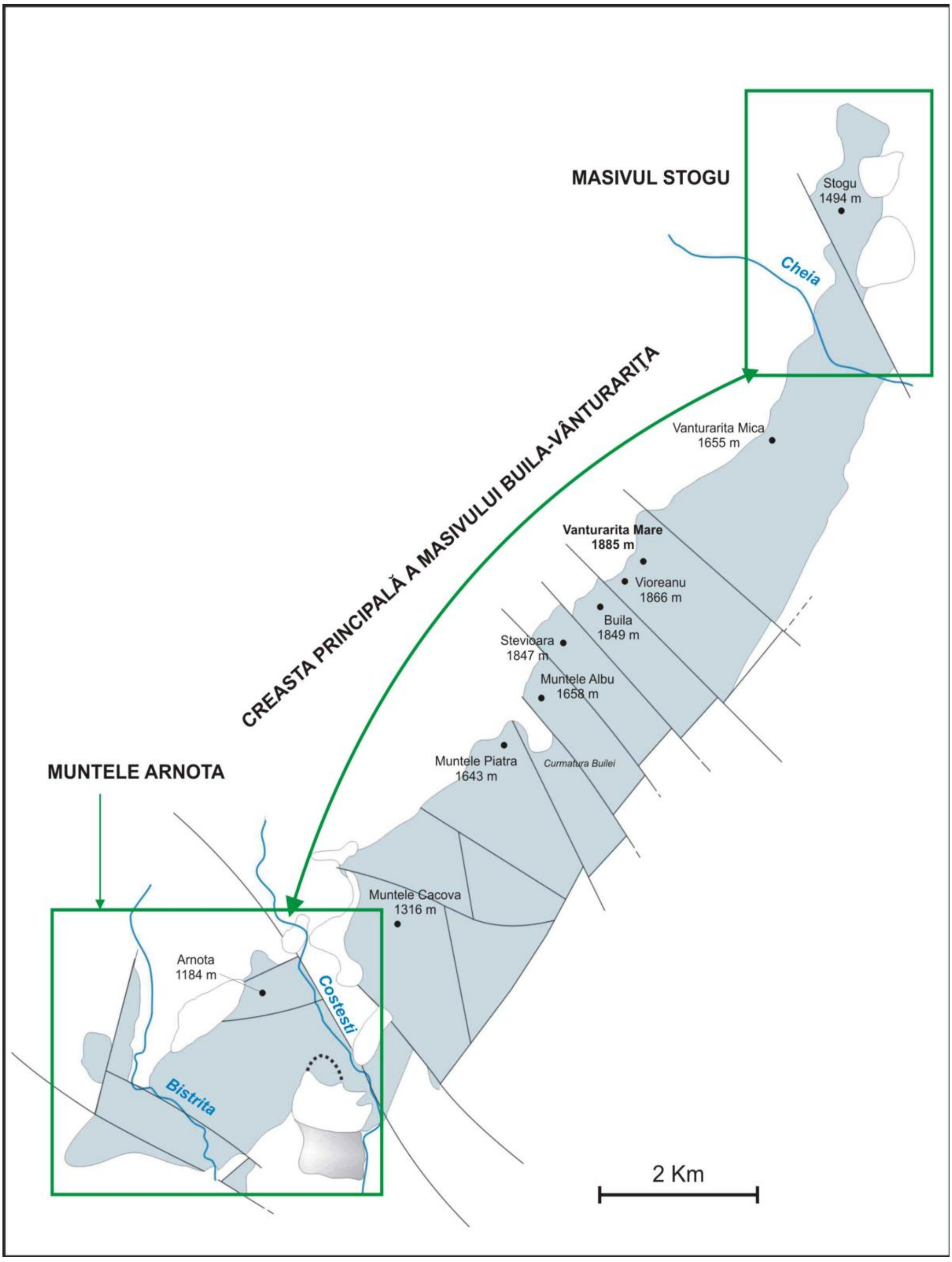

Fig. 2 – Buila-Vânturariţa Massif – general map (after Lupu et al., 1978).

CHAPTER 2. Geological research history from the Buila-Vânturariţa Massif

During the end of the nineteenth century and the first half of the twentieth century, information on the structure of Buila-Vânturariţa deposits are reduced in number and fairly brief. These are often referred in studies on neighboring regions, or within a few detailed studies on this massif.

Some of the oldest geological data on the deposits of Buila-Vânturariţa Massif belong to **Mrazec & Murgoci (1898)**. **Murgoci (1907)**, by the time he was studing the Tertiary deposits of Oltenia, mentioned that the flysch formations from Vânturariţa region belong to the Late Cretaceous (Cenomanian-Senonian) and Paleocene. **Popescu-Voiteşti & Murgoci (1910)** attributed the Jurassic (Malm) age to the limestones of the Buila-Vânturariţa Massif, and also some sandstone deposits from their base. **Popescu-Voiteşti (1915)** reported in the Stogu Massif area, sandstones and conglomerate with red matrix and assigned them to the Middle Jurassic. **Streckeisen (1930)** attributed the limestones of the Buila-Vânturariţa Massif to the Late Jurassic and the sandstones and conglomerates from their base to the Lower Jurassic. The research made by **Popescu (1952, 1954)**, have made a significant contribution to the knowledge of the stratigraphy of the region. **Codarcea et al. (1967)** have made important contributions regarding the Supragetic Unit. **Lupu & Lupu (1967)** showed, based on mollusc fauna from the Valea lui Stan area, the presence of Triassic (Werfenian) in a small portion of northern part of the massif. **Popescu & Patrulius (1968)** showed that the sequence of the Cretaceous deposits in northern part of the massif consists of four complexes, forming two cycles (Vraconian - Cenomanian - Turonian and Campanian - Maastrichtian. In **1968, Boldur et al.,** have paleontologicaly attested the existence of Middle Jurassic under the massive Kimmeridgian - Tithonian reef limestones. **Todiriţă-Mihăilescu (1973)** confirmed the age Coniacian - Santonian of the Cretaceous complex based on the identification of a rich ammonite fauna. **Dragastan (1980)** conducted the first microfacies studies on the Upper Jurassic – Lower Cretaceous limestone deposits of the Buila-Vânturariţa Massif. In **2003, Uţă & Bucur** brought new data regarding the associations of microfossils and microencrusters from the Upper Jurassic - Lower Cretaceous limestones from this massif. More recently, studies on sedimentary deposits in the Buila-Vânturariţa area were performed by **Damian & Lazăr (2005)** and **Neagu & Damian (2005)**, between the valleys of Olăneşti and Cheia rivers, at the boundary between Upper Jurassic - Lower Cretaceous limestone and Upper Cretaceous siliciclastic deposits. **Dragastan (2010)** separated the carbonate deposits of Buila-Vânturariţa Massif in two lithostratigraphic units: the Vânturarița Formation and Stogu Formation. The Vânturarița Formation have the following subunits: the Buila Member (Bajocian - Bathonian - Callovian – Lower and ?Middle Oxfordian - Kimmeridgian), the Bistrița Member (Upper Oxfordian - Kimmeridgian – Tithonian) and the Arnota Member (Neocomian). The Stogu Formation (Barremian - Lower Aptian) contains the following subunits: the Costești Member (Barremian) and the Căprăreasa Member (Lower Aptian). In **2013, Pleş et al.,** conducted a detailed study on microbial crusts and encrusting micro-organisms from the Upper Jurassic (Kimmeridgian - Tithonian) limestone deposits of the Buila-Vânturarița and Piatra Craiului massifs.

CHAPTER 3. The geology of the Buila-Vânturarița Massif.

The Buila-Vânturariţa Massif represents a part of Getic Nappe, a structural unit of the Median Dacides from the Southern Carpathians (**Săndulescu, 1984**). The crystalline formations from the Buila-Vânturariţa Massif belong to the Sebes-Lotru lithofacies, which is dominated by migmatites and gneisses.

The post-Triassic sedimentary deposits are represented mostly by detrital rocks in the Middle Jurassic, overlaid by the Kimmeridgian-Tithonian massive reef deposits. Upper Cretaceous is well developed in the north-eastern part of the region, the deposits of this period being grouped in three distinct complexes.

T R I A S S I C

Triassic deposits outcrop in small areas in the northern part of the region (Valea lui Stan). The base of these deposits is made of siliciclastic rocks, having elements from the crystalline basement, and consist of conglomerates, micro-conglomerates and sandstones. On the top of these, a series of fine sandstone and marls is present. **Lupu & Lupu (1967)** described a Triassic fauna from the deposits mentioned above, including *Myophoria costata*, *Myophoria* sp., *Gervilleia (Angustella)* aff. *angusta alberte*,, attributing the Werfenian age to these deposits.

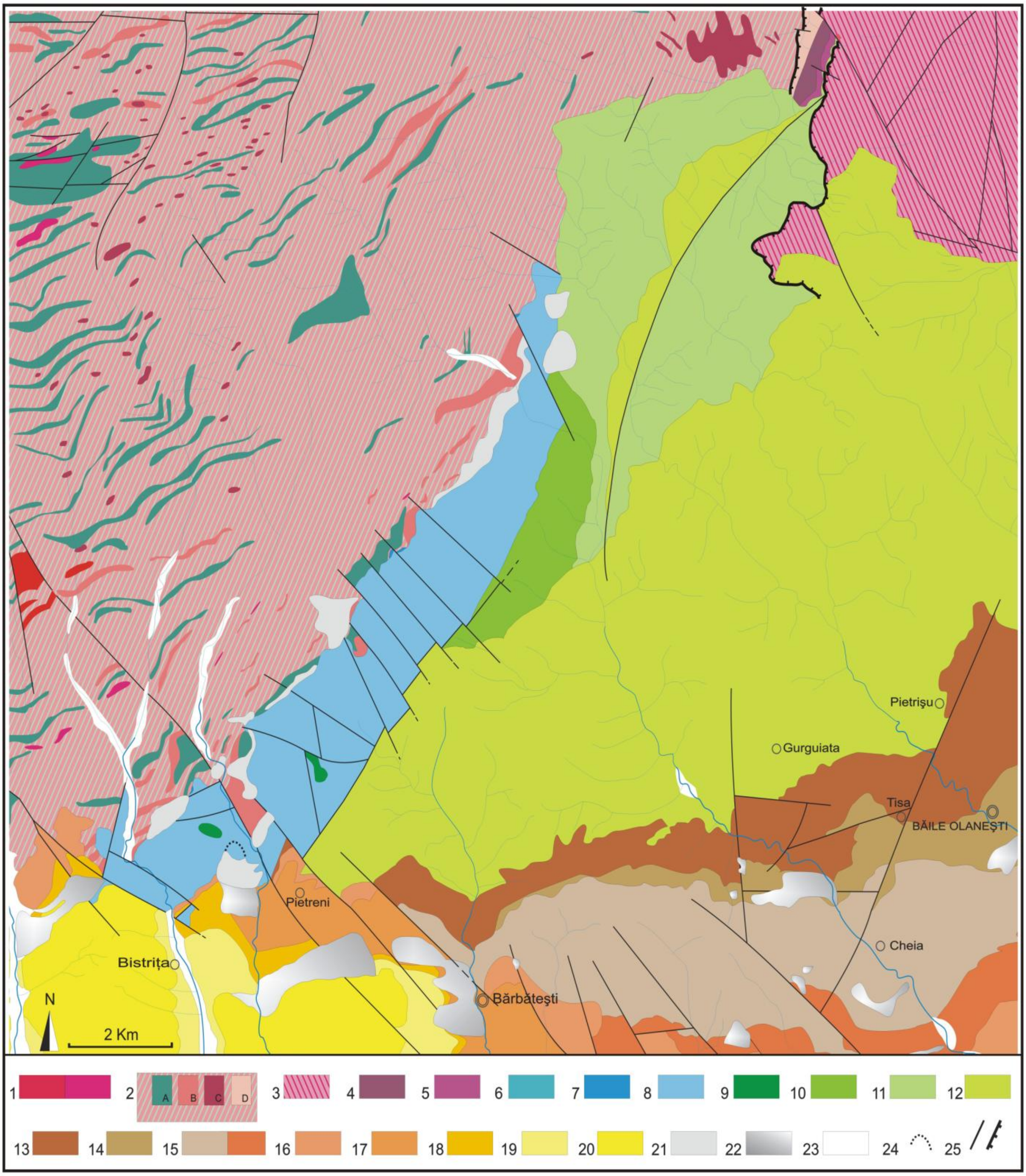

Fig. 3 – Geological map of the Buila-Vânturariţa Massif (modified after Lupu et al., 1978); 1-Magmatic rocks; 2-Sebeş-Lotru lithogroup; 3-Cozia lithogroup; 4,5-Triasic; 6-Bajocian-Callovian; 7-Callovian-Oxfordian; 8-Kimmeridgian-Tithonian; 9-Barremian-Aptian; 10-Albian-Cenomanian; 11-Coniacian-Santonian; 12-Campanian-Maastrichtian; 13-Ypresian-Lutetian; 14-Lutetian-Priabonian; 15-Oligocene; 16,17-Lower Miocene; 18-Middle Miocene; 19,20-Upper Miocene; 21,22,23-Quaternary deposits; 24-Arnota quarry;

J U R A S S I C

The Jurassic deposits of Buila-Vânturariţa Massif are well represented and composed of detrital and siliceous rocks in the Middle Jurassic, overlaid by reef carbonate deposits belonging to the superior levels of the Jurassic period (Oxfordian-Kimmeridgian-Tithonian) (**Dragastan, 2010)**.

In the northwestern part of the massive, the sedimentary formations of the Middle Jurassic appear as lenticular outcrops, such as those from the west of the Stogu Peak or Buila Sector. The Upper Jurassic is present almost completely, being well represented on the Kimmeridgian-Tithonian interval, consisting of massive reef limestone forming the main body of the Buila-Vânturariţa ridge (**Uță & Bucur, 2003**).

C R E T A C E O U S

The Neocomian (Berriasian - Valanginian) outcrop in small areas and it is covered transgressively by Urgonian facies limestones (**Dragastan, 1980, Uță & Bucur, 2003**). Upper Cretaceous deposits are predominantly detrital, represented mostly by sandstones, marls and conglomerates (**Todoriţă-Mihăilescu, 1973**). **Boldur et al.** (**1970**) separated in these deposits, three distinct complexes: Vraconian-Cenomanian-Turonian, Coniacian-Santonian and the Campanian-Maastrichtian complex.

C E N O Z O I C

Cenozoic sediments had been identified in this region belonging to the Eocene, Oligocene and Miocene. The Eocene-Oligocene boundary can be well seen in the Valea Cheii Gorges, where Oligocene deposits are outcroping over Eocene conglomerates. Miocene deposits are present in the region represented by sandstones, shales and sands. The Quaternary sediments consist of alluvial deposits of Bistrița, Otăsău and Olăneşti rivers, and landslides or alluvial cones.

CHAPTER 4. Work methodology

4.1. Field-work stage

Durring this stage, I have collected a total of 1250 samples, ranging in size from 10 to 15 cm, from eight different areas (profiles) within the Buila-Vânturariţa Massif. The sampling process is done using the geological hammer and a chisel (when applicable). The resolution was determined by the specifics of each profile, sampling routes (profiles) being marked by the GPS points.

4.2. Laboratory stage

Samples collected from the Buila-Vânturariţa Massif were processed in the laboratory of the Department of Geology in order to perform thin sections (1270 sections) for petrographic analysis. Some of the collected samples were prepared for polished slabs, and for cathodoluminescence analysis.

4.3. Petrographic analysis

Microfacies analysis

Microfacies analysis involves the identification of textures, internal structures and specific diagenetic processes in order to determine depositional environments, facies associations and their evolution or biostratigraphic interpretations. For the description of carbonate rocks, 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)**.

Cathodoluminescence

Cathodoluminescence analyses were conducted at the Faculty of Geology and Geophysics from University of Bucharest.

Cathodoluminescence is actually a photon emission (luminescence) presented by some solid objects or substances after an electron bombardment. Luminescence depends on the characteristics of the sample under analysis. Among these features, the most important are the chemistry and crystal structure. Carbonate luminescence in the visible spectrum can be generated by certain impurities (also called activators) such as Mn^{2+} emission spectrum generated by these ions is orange-red or orange - yellow. The decrease in luminescence can be caused by the presence of carbonate ions Fe^{2+} , Co^{2+} and Ni^{2+} (inhibitors) , which can capture all or part of the excitation energy (Panaiotu, 2000) .

Flügel (2004), presents the main applications of cathodoluminescence in the study of carbonate rocks:

- Observation and interpretation of diagenetic processes;
- Identification of cementing stages;
- Recognition of certain fabrics;
- Studies of diagenesis on certain groups of fossils;

CHAPTER 5. Profile description.

5.1 Cheile Bistriţei Vâlcene (P1)

This profile is located in the south-western extremity of the massif and was carried through the gorge sector of Bistrita river. The sedimentary sequence of Bistriței Gorges consists of large levels of carbonatic reef breccias / micro-breccias intercalated with coral - microbial bioconstructions. Packstone and grainstone appear subordinate. We identified two major types of facies: **TMF1** – intraclastic-bioclastic rudstone/grainstone and **TMF2** - coraligen-microbial boundstone. The main microfacies types for **TMF1** are represented by intraclastic-bioclastic rudstone and coarse intraclastic-bioclastic grainstone. Bioconstructions (**TMF2**) appear interbedded in the lower and upper part of the succession and are developed over the intraclastic-bioclastic rudstone/grainstone facies. In the coraligen-microbial bioconstructructions we identified the following microfacies sub-types: microbial bindstone, framestone and sporadically bafflestone.

In Table 1 are listed the most important microfossils, in terms of biostratigraphy. The association with *Clypeina sulcata, Salpingoporella pygmaea, Nipponophicus ramosus, Charentia evoluta, Andersenolina alpina* indicates an Upper Jurassic age (**Bucur, 1999 Schlagintweit et al., 2005**). **Dragastan** (**1975**), **Bucur and Sasaran** (**2005**), **Sasaran** (**2006**), **Bucur et al.** (**2010**). **Pleş et al.** (**2013**) described similar associations for the Kimmeridgian-Tithonian interval from some carbonate deposits in Romania.

Taxon / Range	OXFORD.	KIMMER.	TITHON.	BERRIAS.	VALANGIN.
Andersenolina alpina **(Leupold)**	━━	━━	━━	━━	━━
Bullopora aff. *laevis* **Sollas**	━━	━━	━━	━━	━━
Charentia evoluta **(Gorbachik)**			━━	━━	
Protopeneroplis ultragranulata **(Gorbachik)**			━	━━	━━
Clypeina sulcata **(Alth)**	━━	━━	━━	━━	
Salpingoporella pygmaea **(Guembel)**	━━	━━	━━	━━	━━
Nipponophycus ramosus **Yabe & Toyama**		━━	━━	━━	– –
Thaumatoporella parvovesiculifera **(Raineri)**	━━	━━	━━	━━	━━
Crescentiella morronensis **(Crescenti)**	━━	━━	━━	━━	━━
Iberopora bodeuri **Granier & Berthou**		━━	━━		
Koskinobullina socialis **Cherchi & Schroeder**	━━	━━	━━	━━	━━
Lithocodium aggregatum **Elliott**	– –	– –	– –	– –	– –
Perturbatacrusta leini **Schlagintweit & Gawlick**	━━	━━	━━	━━	
Radiomura cautica **Senowbari-Daryan & Schäefer**	━━	━━	━━	━━	━━
Neuropora lusitanica **Termier & Termier**	━━	━━	━━		
Thalamopora lusitanica **Termier & Termier**	━━	━━	━━		
Calcistella jachenhausenensis **Reitner**			━━		

Table 1 - Main microfossils identified in the limestones of Bistrita Gorges

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In the carbonate sequence of Bistrita Gorges, the predominant facies is given by breccias and reef micro-breccias. The microbial crusts and sometimes sindepositional cements (fibrous radiaxial cement) acted as stabilizers and binders of slope facies. Subsequently, the substrate became stable and favorable to the installation of coral-microbial bioconstructions. Coarse reef facies (breccias/micro-breccias) emphasize the slope instability.

An important aspect is the presence of the enigmatic micro-organism *Epiphyton* in the Upper Jurassic limestones of Bistrita Gorges, microorganism known so far only from Paleozoic. Recently it has been discovered in other Kimmeridgian-Tithonian deposits in Romania and makes the subject of a study in precess of elaboration (**Sasaran et al.**, in preparation).

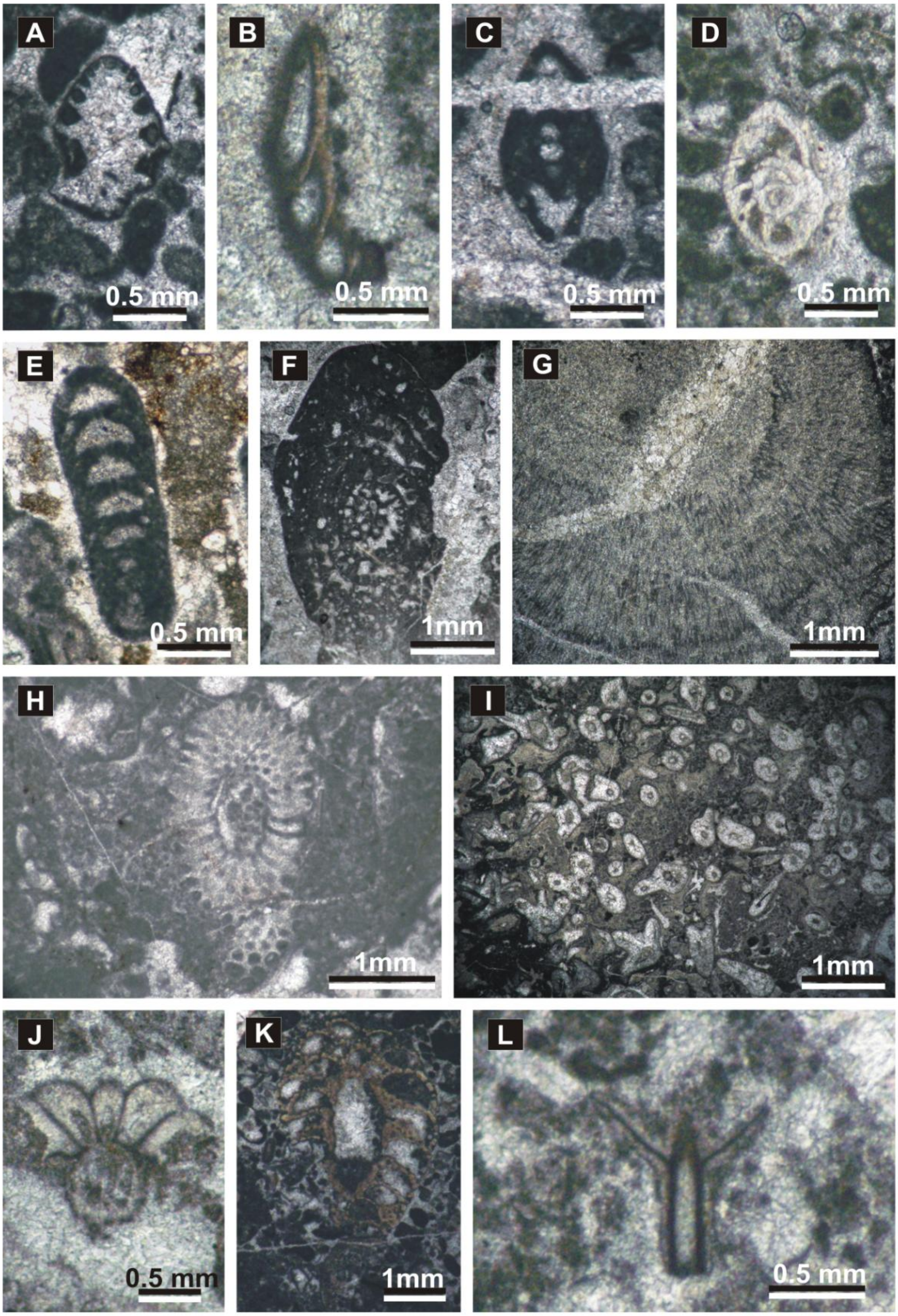

Fig. 4 – Microfossils from Bistriţei Gorges: A-*Andersenolina delphinensis*; B-*Mohlerina basiliensis*; C-*Charentia evoluta*; D-*Lenticulina* sp.; E-*Lituola baculiformis*; F-*Coscinophragma cribrosa*; G-"*Solenopora*" sp.; H-*Salpingoporella pygmaea*; I-*Niponophycus ramosus*; J-*Clypeina sulcata*; K-*Thalamopora lusitanica*; L-*Mercierella dacica*.

5.2 Arnota Sector(P2)

The profile from Arnota Sector is located in the central-eastern part of Mount Arnota. The carbonate deposits that outcrop here consist mainly of Upper Jurassic reef micro-breccia intercalated with packages of bioconstructed limestones. In the upper part of the succession we identified micritic limestones with fenestral-laminar structures and stromatolitic sequences.Within this successsion were separated four major types of facies: 1 – Bioclastic-intraclastic floatstone/rudstone (**TMF1**); 2 – Coraligen-microbial boundstone (**TMF2**); 3 – Bioclastic peloidal-fenestral wackestone/packstone (**TMF3**) and 4 - Microbial wackestone (**TMF4**). The major facies type for the Lower Cretaceous carbonate deposits is represented by bioclastic peloidal wackestone with fenestrae (**TMF5**).

The Kimmeridgian-Tithonian age for these deposits was established by calcareous algae associations and foraminifera. Among these, the most important are the following: calcareous algae (*Salpingoporella pygmaea*, *Clypeina sulcata*, *Thaumatoporella parvovesiculifera* and *Nipponophycus ramosus*); foraminifera (*Charentia evoluta, Andersenolina alpina, A. delphinensis, Lenticulina* sp., *Lituola baculiformis*, *Coscinophragma sp.*, *Protopeneroplis ultragranulata* and *Troglotella incrustans*). In addition to these microfossils, numerous associations of encrusting microorganisms and sclerosponges have been identified, forms typical for Upper Jurassic, like: *Crescentiella morronensis*, *Lithocodium aggregatum*, *Bacinella*-like structures, *Radiomura cautica, Perturbatacrusta leini*, *Neuropora lusitanica, Thalamopora lusitanica*. Micropalaeontological diversity of Lower Cretaceous deposits (Lower Barremian-?Aptian), is poorer than the Upper Jurassic deposits, the most important species for establishing the age are the following foraminifera: *Parakoskinollina jourdanensis, Paracoskinolina* sp., *Vercorsella camposaurii* and *Everticyclammina* sp.

Unlike the first profile from Bistritei Gorges in Mount Arnota, specifically the first half of the sequence, we can see a clear dominance of reef slope deposits. These are mostly micritic (floatstone/rudstone) associated with small levels of coraligen-microbial bioconstructions probably developed in the form of "patch reef". Over these deposits are transgressively disposed the Lower Cretaceous deposits, formed in restrictive environments from intertidal areas.

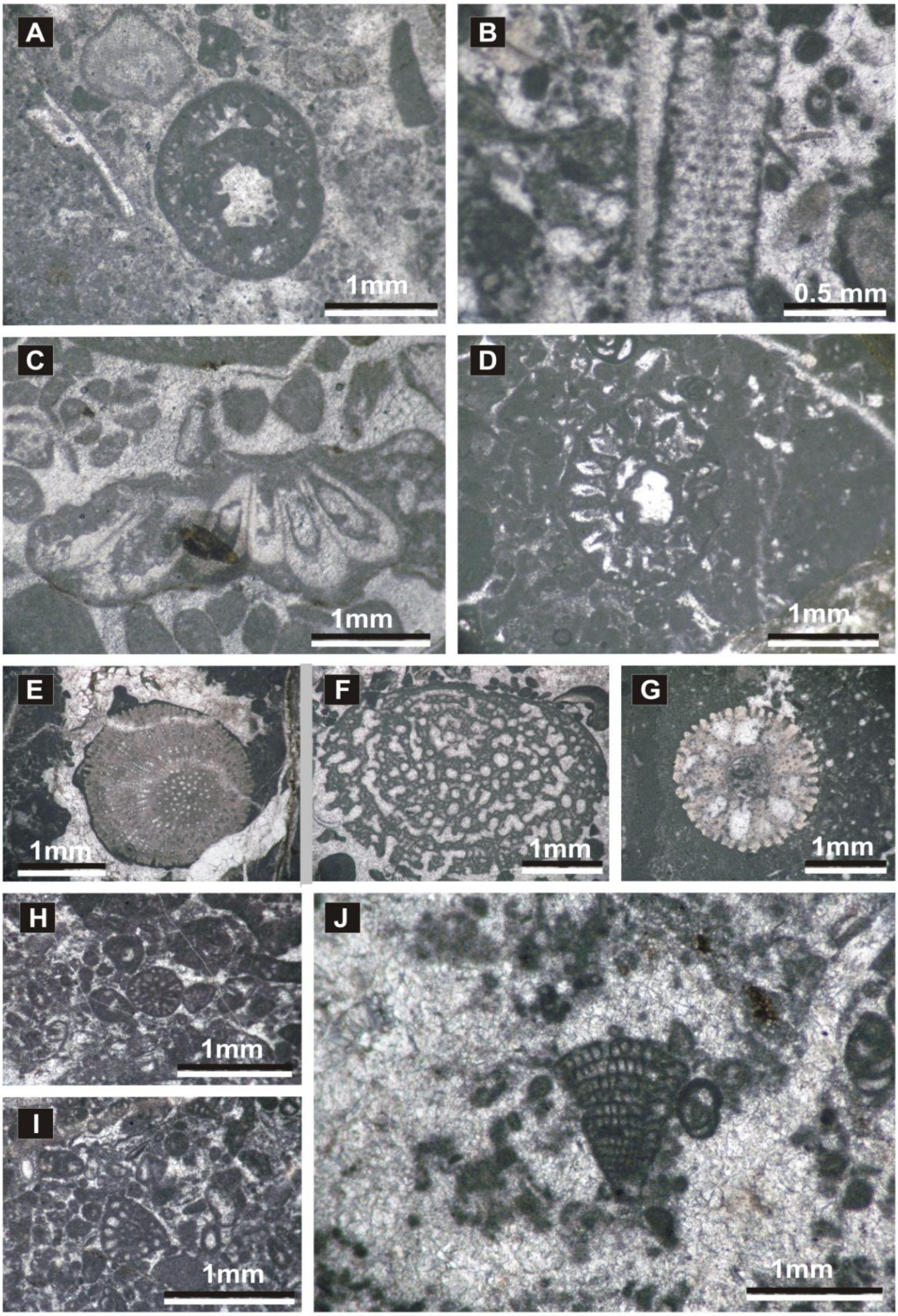

Fig. 5 – Microfossils from Arnota Sector: A–?*Everticyclammina* sp. ; B-Fragment of *Salpingoporella pygmaea*; C– *Clypeina sulcata*; D–*Clypeina* sp. ; E–*Neuropora lusitanica*; F-*Cylicopsis verticalis*; G-*Thalamopora lusitanica*; H-*Paracoskinolina* sp.; I-*Paracoskinolina* cf. *jourdanensis*; J-*Vercosella camposaurii*.

5.3 Costeşti Gorges (P3)

The Costeşti Gorges are located in the southeastern part of Buila-Vânturariţa Massif and cross the massif from north to south with a length of about 2 km. The main facies for the Upper Jurassic carbonate deposits of the Costeşti Gorges are similar to those identified in the first two sampled sequences. They are composed of reef coral micro-breccia layers associated with packages of coral-microbial bioconstructions with stromatoporoids. Bioclastic-intraclastic grainstone/rudstone (**TMF1**) and microbial-recifal boundstone (**TMF2**) are the major facies types for the Jurassic carbonate succession from Costeşti Gorges. Lower Cretaceous deposits are predominantly muddy, represented by bioclastic wackestone and peloidal bioclastic wackestone. Within these we identified a main type of facies: **TMF3** - bioclastic peloidal wackestone / packstone.

The micropalaeontological association consists of: encrusting sponges (*Petrurbatacrusta leini, Neuropora lusitanica*, *Ellipsactinia* sp., *Thalamopora lusitanica*, *Actinostromaria* sp., *Cylicopsis verticalis*), foraminifera (*Lenticulina* sp., *Lituola baculiformis, Coscinophragma sp., Andersenolina alpina, A. delphinensis*, *Protopeneroplis ultragranulata*, *Troglotella incrustans*), calcareous algae (*Salpingoporella pygmaea*, *Clypeina sulcata*, *Nipponophycus ramosus*, *Thaumatoporella parvovesiculifera*) and encrusting microorganisms (*Crescentiella morronensis*, *Labes atramentosa*, *Lithocodium aggregatum*, *Bacinella*-like structures, *Radiomura cautica*, *Koskinobulina socialis*). Based on this micropalaeontological association, the age of Jurassic deposits can be attributed to the Kimmeridgian – Upper Tithonian age. For Lower Cretaceous, the following association was identified: *Parakoskinolina jourdanensis*, *Vercorsella camposaurii*, *Vercorsella* cf. *camposaurii*, *Charentia* sp., *Everticyclammina* sp., *Lithocodium aggregatum* and *Bacinella*-like structures. Based on this association of foraminifera and calcareous algae we determined the age of the deposits: Lower Barremian-Aptian.

Unlike the first two analyzed sequences, to notice is the large presence of stromatoporoids in the composition of bioconstructions, especially *Ellipsactinia* sp., *Neuropora lusitanica* or *Cylicopsis verticalis*, common species in Upper Jurassic rimmed platforms from Intra-Tethysian domains (**Leinfelder et al., 2005**).

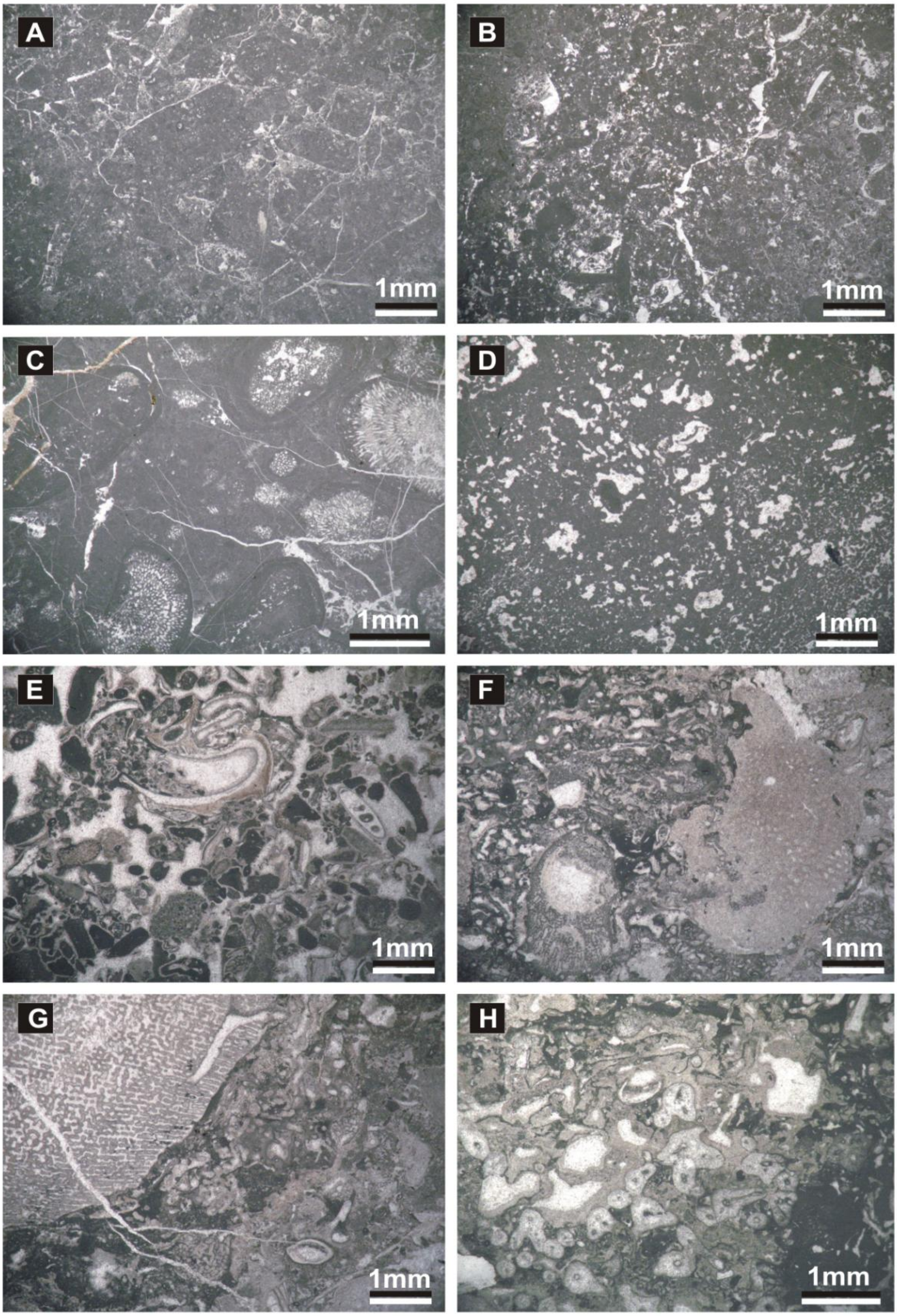

Fig. 6 – Main microfacies from Costeştilor Gorges: A, B- Bioclastic-peloidal-intraclastic wackestone; C- Bioclastic-oncoidal wackestone with rivulariacean cyanobacteria; D- Peloidal-fenestral wackestone; E– Reef bioclastic-intraclastic coarse grainstone/rudstone; F, G, H- Coraligen-microbial boundstone with encrusting organisms, stromatoporoids and *Nipponophycus.*

5.4 Cacova Sector (P4)

Cacova sector (Mount Cacova) is located in the southeastern part of the main ridge of Buila-Vânturariţa Massif. The main facies for the Jurassic carbonate succession on Mount Cacova is represented by gravity flow deposits (deposits derived from reef areas), peloidal-bioclastic wackestone and coral-microbial bioconstructions. We have identified three major types of facies: 1-Bioclastic grainstone/rudstone (**TMF1**) 2-Coral-microbial boundstone (**TMF2**) and 3-Bioclastic wackestone/packstone (**TMF3**). Lower Cretaceous limestones in Urgonian facies are represented by bioclastic-peloidal wackestone and packstone with foraminifera (**TMF4**).

Within the carbonate succession from Mount Cacova, were intercepted mostly Upper Jurassic deposits, and also Lower Cretaceous deposits developed in Urgonian facies. The age of these deposits was established on calcareous algae and foraminifera. For the Upper Jurassic (Kimmeridgian-Tithonian), the following association was identified: foraminifera (*Lenticulina* sp., *Lituola baculiformis*, *Andersenolina alpina*, *Mohlerina basiliensis*, *Coscinophragma* sp., *Troglotella incrustans*), calcareous algae (*Clypeina sulcata*, *Salpingoporella pygmaea*), stromatoporoide (*Petrurbatacrusta leini*, *Neuropora lusitanica*, *Ellipsactinia* sp., *Cycliopis verticalis*), cyanobacteria (*Rivularia* sp.) and microproblematica (*Crescentiella morronensis*, *Labes atramentosa*, *Lithocodium aggregatum*, *Radiomura cautica* and *Bacinella*-type structures). For the Lower Cretaceous deposits (Barremian-Aptian), the following species were identified: *Parakoskinolina jourdanensis*, *Vercorsella* sp., *Charentia cuvillieri*, *Nautiloculina broennimanni*, *Pfenderina globosa*, *Pseudolituonella* sp., *Quinqueloculina robusta*, *Bacinella*-type structures, *Lithocodium aggregatum* and *Troglotella incrustans.*

In the calcareous deposits of Mount Cacova was observed alternating facies and microfacies for the Upper Jurassic-Lower Cretaceous interval. From the fore-reef environments or reef slope to shallow-marine sedimentation, like in the upper part of the succession with fenestral-micritic facies. Starting with the middle part of the profile, we have frequently found, fissures or cavities filled with fine clayey sediment. The poor occurence of bioconstructions, laminitic microbial structures (stromatolites) or reef breccias (bioclastic-intraclastic rudstone) from Mount Cacova, is a further argument in transition from slope or reef crest areas to shallow environments typical for the internal platform depositional areas.

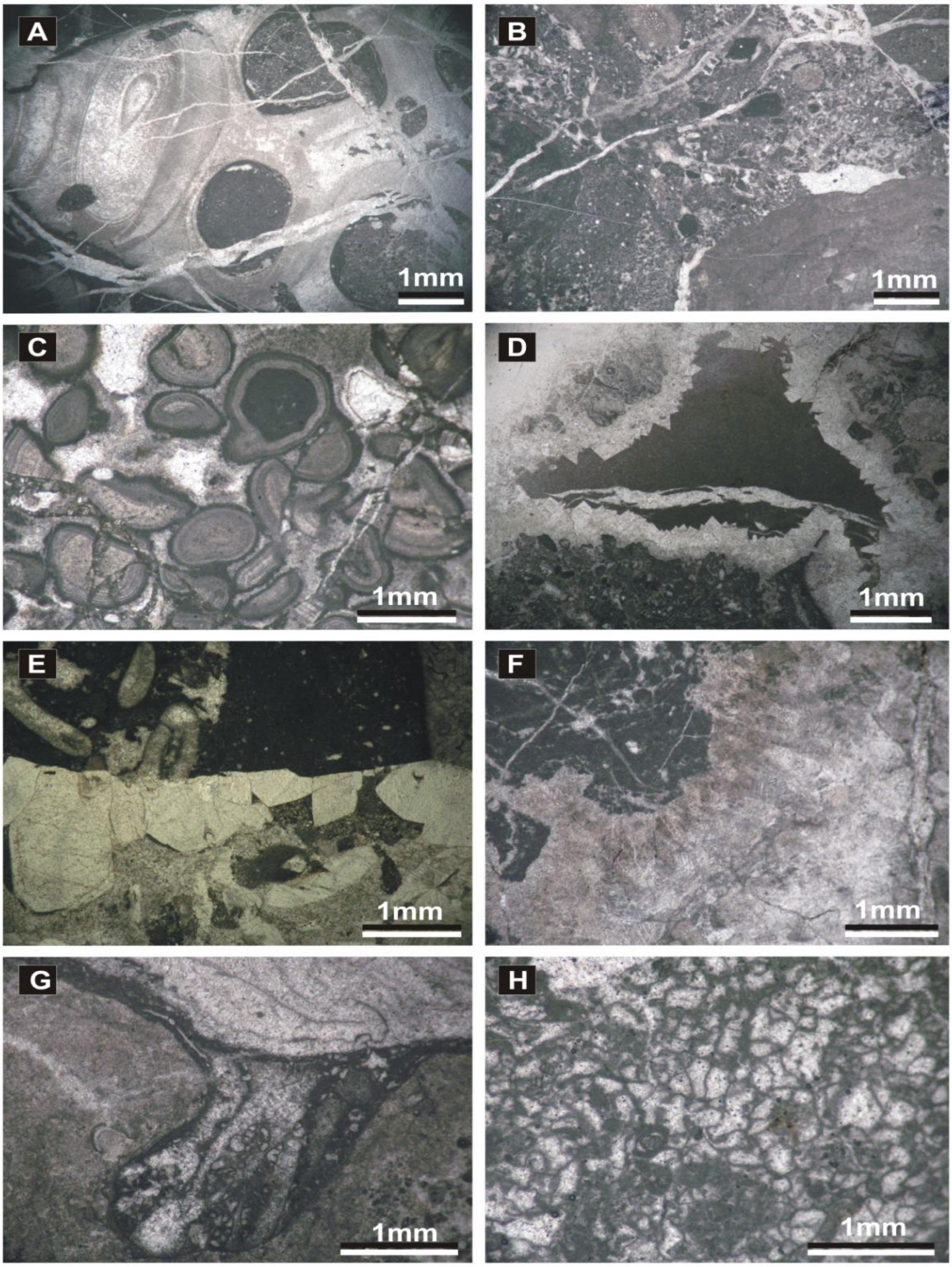

Fig. 7 – Microfacies characteristics from Cacova Sector: A – Large gastropod with the chambers filled with fine micritic sediment; B – Clotted microbial crusts and *Crescentiella morronensis* stabilizing the reef slope sediment; C – Ooidal level; D, E – Cavities with clay infilling bordered by “dog-tooth” cement type; F – Cements in the micritic facies; G, H – *Bacinella*-type microbial structures.

5.5 Albu Mountain (P5)

This profile was performed on the right side of Curmătura Builei, located in the central part of the Buila-Vânturariţa Massif. The carbonate succession of Mount Albu consists mainly of Upper Jurassic deposits consisting of alternating reef slope limestones (micro-breccias and reef detritus) with bioconstructed deposits and fine-granular flow deposits. In this profile we identified four major types of microfacies for the Upper Jurassic deposits: **TMF1** - intraclastic-bioclastic rudstone/grainstone, **TMF2** - coral-microbial boundstone, **TMF3** - fine bioclastic-peloidal grainstone and bioclastic-peloidal wackestone/packstone (**TMF4**). The main facies type for the Barremian-Aptian deposits is represented by bioclastic-peloidal wackestone/packstone with diaclase (**TMF5**).

The micropaleontological content of the reef deposits (Kimmeridgian-Tithonian) is quite diverse in terms of species and comprises besides corals, encrusting stromatoporoids (*Petrurbatacrusta leini*, *Neuropora lusitanica*, *Ellipsactinia* sp., *Thalamopora lusitanica*, *Murania reitnieri*, *Calcistella jachenhausenensis*, *Calciagglutispongia yabei*, *Actinostromaria* sp., *Cylicopsis verticalis*, *Tubuliella fluegeli*), foraminifera (*Lenticulina* sp., *Ammobaculites* sp., *Acruliammina* sp., *Lituola baculiformis*, *Mohlerina basiliensis*, *Coscinophragma* sp., *Andersenolina alpina*, *Protopeneroplis ultragranulata*, *Troglotella incrustans*), calcareous algae (*Salpingoporella pygmaea*, *Clypeina sulcata*, *Nipponophycus ramosus*, *Thaumatoporella parvovesiculifera*) and microproblematica. The microfossil association from the Lower Cretaceous deposits (Barremian-Aptian) consists of the following species: *Parakoskinolina jourdanensis*, *Vercorsella hensoni*, *Charentia* sp. and *Bacinella*-type structure.

Starting with the lower part of the succession, the bioconstructions contain a fine bioclastic-intraclastic internal sediment and they are interlayered with finer granular flow deposits (fine bioclastic grainstone), which emphasizes an environment with a high hydrodynamic, probably above wave base. Based on the data presented it can be concluded that there is a gradual transition from lower shelf slope facies to the shelf edge facies, reef body or to internal environments of the carbonate platform..

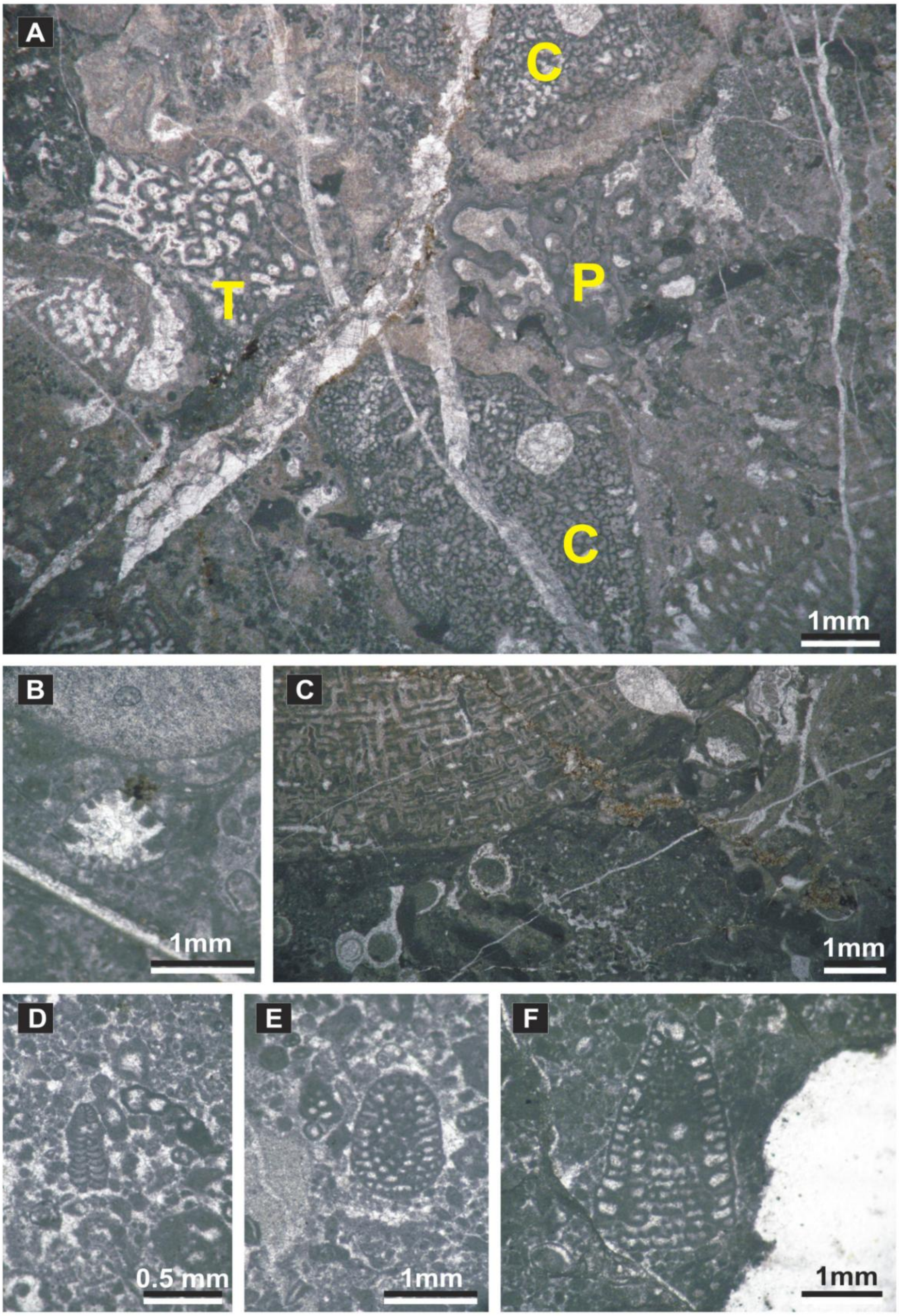

Fig. 8 – Microfossils from Mount Albu: A – Stromatoporoid bioconstruction (*Cylicopsis verticalis* (C), *Tubuliella fluegeli* (T)) and *Perturbatacrusta leini* (P); B - *Andersenolina alpina*; C – Encrusting sclerosponge and worm tubes; D-*Vercorsella* sp.; E, F - *Parakoskinolina jourdanensis*.

5.6 Schitul Pahomie - Șaua Ștevioara (P6)

This profile is located in the central part of the Buila-Vanturarita Massif. The sampled sequence is located between Schitul Pahomie and Șaua Ștevioara, near Vânturariţa Mare Peak.

Within this sector of the limestone succession from Buila-Vânturariţa, we identified four different types of carbonate deposits which, from bottom to the top of the sequence are: fine granular flow deposits, coral-microbial bioconstructions with sponges, reef micro-breccia and micritic limestones. The major microfacies types are given by: coarse bioclastic grainstone/rudstone (**TMF1**), coral-microbial boundstone (**TMF2**), fine packstone/grainstone (**TMF3**) and bioclastic peloidal wackestone/packstone (**TMF4**).

In this sector we intercepted Upper Jurassic deposits (Kimmeridgian-Tithonian) and Lower Cretaceous deposits in Urgonian-type facies (Barremian-Aptian). The microfossils associations of foraminifera and calcareous algae in particular, allowed us to establish the age mentioned above for these carbonate deposits.

In terms of depositional processes, in these carbonate deposits, it is noted that there is a gradual transition of. Lower slope, upper slope, reef body (?" Patch reef") and lagoon, are the main depositional environments identified in the limestone succession of Ştevioara sector. Stromatolitic meso-structures found in large numbers and some encrusting microorganisms (*Crescentiella morronensis*) consolidated the slope sediments and strengthened the reef framework.

The main feature of the micritic facies is the presence of large *bacinellid* oncoids associated with rivulariaceean-type cyanobacteria or benthic foraminifera.

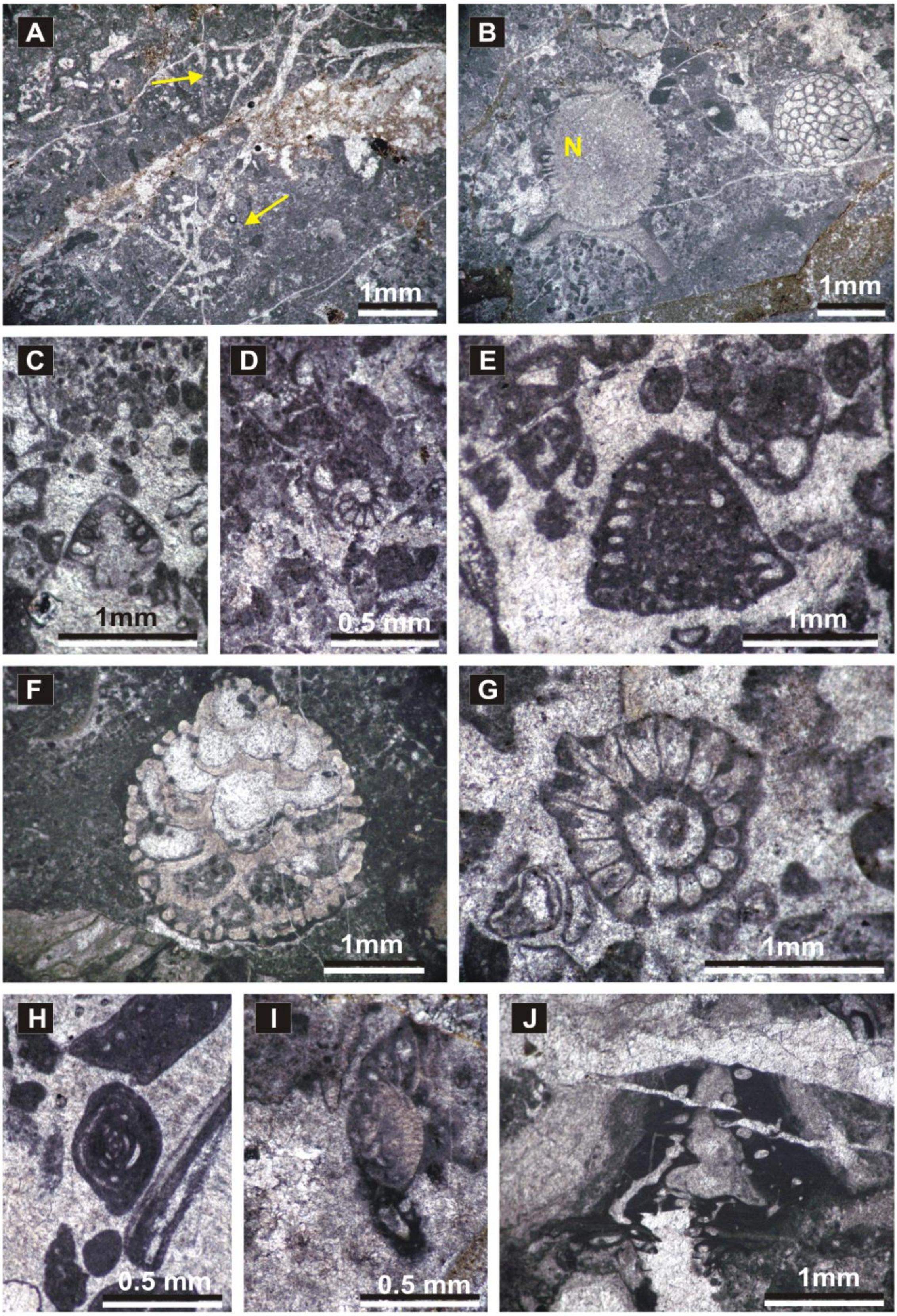

Fig. 9 – Microfossils from Ștevioara Sector: A-*Coscinophragma cribrosa* (arrows); B-Encrusting stromatoporoids; *Neuropora lusitanica* (N) ; C-*Andersenolina alpina*; D-*Protopeneroplis ultragranulata*; E-*Parakoskinolina jourdanensis*; F-*Thalamopora lusitanica*; G-*Clypeina sulcata*; H-Foraminifera; I-*Mohlerina basiliensis*; J– *Labes atramentosa*.

5.7 Schitul Pahomie - Stâna Oale - Curmătura Oale (P7)

This profile is located in the northern part of the mountain and connects the north western slope and the south-eastern ridge of the Buila Vânturariţa Massif. The sedimentary sequence in this sector consists of alternating limestone levels assigned to different areas of the carbonate platform. The major types of facies are similar to many of those identified in the previous profiles: **TMF1** - intraclastic-bioclastic grainstone/ rudstone, **TMF2** - coral-microbial boundstone, **TMF3** – fine reef grainstone/packstone and **TMF4** - bioclastic wackestone/packstone.

The identified micropalaeontological association consists in: encrusting sclerosponges (*Petrurbatacrusta leini, Murania reitneri*, *Calcistella jachenhausenesis, Neuropora lusitanica*, *Thalamopora lusitanica*, *Actinostromaria* sp., *Cylicopsis verticalis*), foraminifera (*Lenticulina* sp., *Lituola baculiformis*, *Coscinophragma sp.*, *Andersenolina alpina*, *A. delphinensis*, *Protopeneroplis ultragranulata*, *Troglotella incrustans, Monsalevia salevensis*), algae (*Salpingoporella pygmaea*, *Clypeina sulcata*) and encrusting micro-organisms (*Crescentiella morronensis*, *Labes atramentosa*, *Lithocodium aggregatum*, *Bacinella*-type structures, *Radiomura cautica*, *Koskinobulina socialis*). The identifying of the following species: *Monsalevia salevensis* or *Protopeneroplis ultragranulata* in the top of this carbonate succession, permited us to establish the Kimmeridgian - Tithonian -?Berriasian age, the boundary between Upper Jurassic and Neocomian being imperceptible. Barremian-Aptian deposits could not be separated based on microfossils, but we can admit their presence within the sequence by the presence of rudists fragments identified in the top of the succession.

The Upper Jurassic carbonate deposits intercepted in this profile from the Buila-Vânturariţa Massif, are similar to those identified in previous profiles. An exception is the fenestral micritic facies with rivulariacean-type cyanobacteria and pisoids intercepted in the second part of the profile, where internal platform facies dominates the succesion.

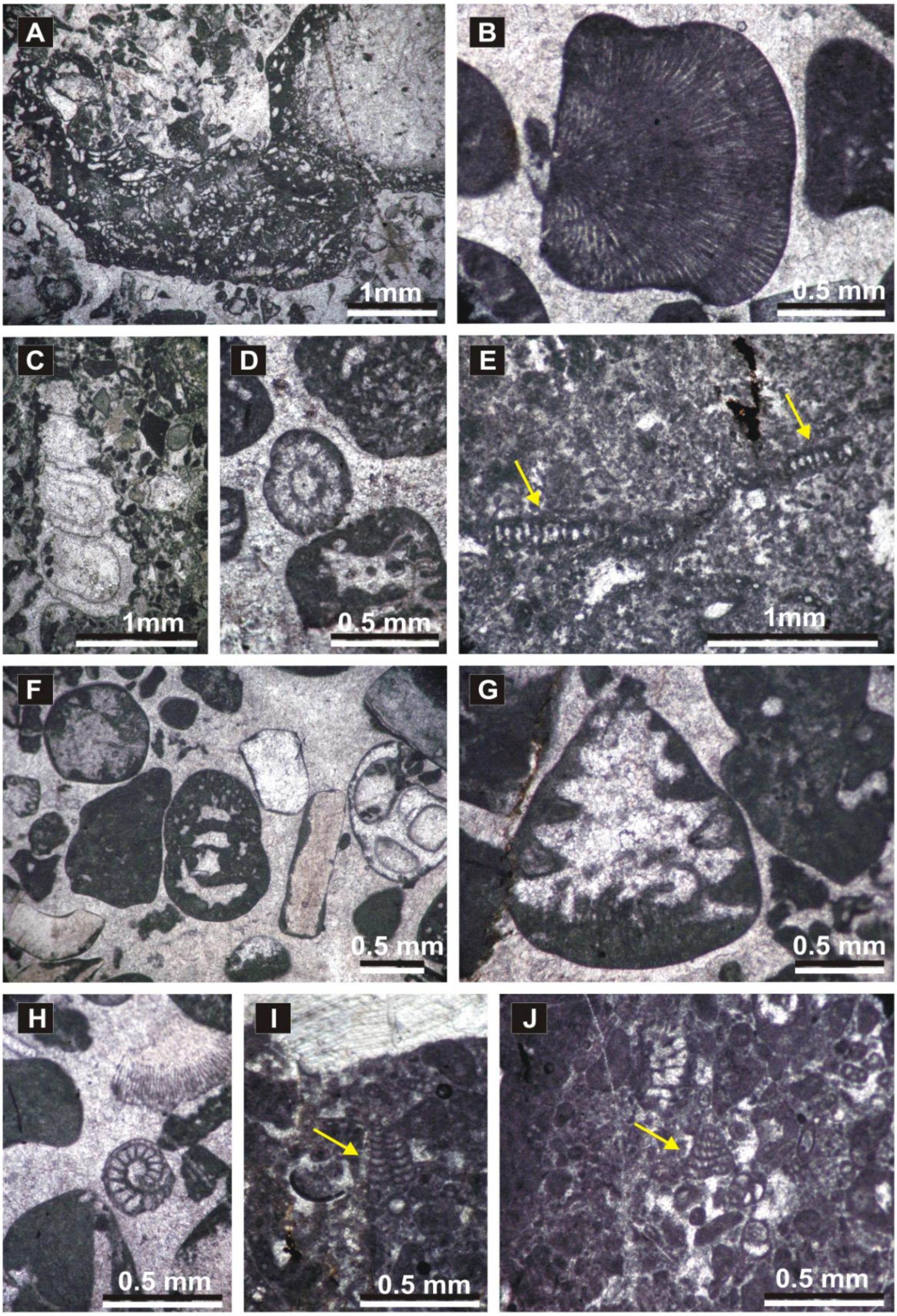

Fig. 10 – Microfossils from Curmătura Oale Sector: A-B*acinella* oncoid; B-S*olenoporacean* algae; C-Gastropod; D-*Salpingoporella pygmaea*; F-Benthic foraminifera; G-*Andersenolina alpina*; H-*Protopeneroplis ultragranulata*; I-J-*Monsalevia salevensis*.

5.8 Cheia Valley (P8)

The profile from CheiaValley is the last profile performed in the Buila-Vânturariţa Massif. This gorge sector is located in the north-eastern part of the massif representing the boundary between the main peak and Stogu Massif. The major microfacies types are: **TMF1** - bioclastic grainstone/rudstone, **TMF2** - coral-microbial boundstone with encrusting organisms and **TMF3** - bioclastic wackestone.

In the Cheia Valley were intercepted only Upper Jurassic deposits. The Kimmeridgian-Upper Tithonian age is confirmed by the following association of microfossils: *Clypeina sulcata, Salpingoporella pygmaea, Charentia evoluta, Andersenolina alpina, Protopeneroplis ultragranulata, Perturbatacrusta leini, Neuropora lusitanica, Crescentiella moronensis* and *Lithocodium aggregatum*. This Upper Jurassic micropalaeontological association is typical for many other areas from the Romanian Carpathians (**Uță & Bucur, 2003; Bucur & Săsăran, 2005; Săsăran, 2006; Pleș et al., 2013**).

The limestone deposits which crop out in the Cheia Valley are characterized by a dominance of reef slope facies, represented by granular flows from the fore-reef area associated with "patch reef" - type bioconstructions. Cement crusts and some microbialites have led to the stabilization of the slope sediments in this area of the massif. The lower part of the micritic sequence is strongly affected by diagenetic processes such as cracks, different generations of cements in cavities or dolomitization processes.

CHAPTER 6. The occurrence and importance of the encrusting micro-organisms and microbial crusts from the carbonate deposits of Buila-Vânturariţa Massif.

Encrusting micro-organisms

Upper Jurassic deposits of the Buila-Vânturariţa, consist predominantly of massive reef limestone, containing a wide variety of microbial crusts associated with many types of encrusting micro-organisms. These micro-organisms played an important role in the development and strengthening of the reef frameworks and they are also considered to be important elements in deciphering and interpreting depositional environments.

The main feature of microbial activity in the Upper Jurassic limestones from the Buila-Vânturariţa Massif is the generation of many types of structures such as stromatolites, thrombolitic crusts, cement crusts, micritic cortices, accompanied by encrusting micro-organisms. Even if the occurrence of many of these "micro-encrusters" within the microbial crusts of Upper Jurassic - Lower Cretaceous is well known, some distinct forms are still organisms with uncertain systematic position, their phylogenetic affiliation being continuously researched in recent decades. The most important species of encrusting micro-organisms for our study are: *Crescentiella morronensis*, *Lithocodium aggregatum*, *Koskinobullina socialis*, *Radiomura cautica* and *Bacinella*-type structures.

In addition to the above micro-organisms, have been reported other important species in the composition of microbial crusts of the Buila-Vânturariţa carbonate deposits: foraminifera (*Coscinophragma* sp.), algae (*Thaumatoporella parvovesiculifera*), microproblematica (*Labes atramentosa*, *Iberopora bodeuri*), encrusting sclerosponges (*Calcistella jachenhausenensis*, *Murania reitneri*, *Neuropora lusitanica*, *Thalamopora lusitanica*), briozoans and serpulids.

Microbial structures

Riding (2000) believes that in terms of macrofabrics the microbial carbonates can be divided into three main types: laminated microbial structures (stromatolites), clotted structures (thrombolic) and structureless microbialites (leiolite). Based on the classification of microbialites, **Schmid (1996)** and **Flügel (2004)** proposed three types of microbial microfabrics: peloidal, laminated and dense. The presence of peloidal microstructures is linked to the presence of thrombolitic fabrics. After the arrangement of peloids, thrombolitic fabrics can divide themselves in poorly structured thrombolites, clotted thrombolites or thrombolic laminated microstructures which are already switching to laminitic microstructures. After **Leinfelder (1993),** thrombolites consist exclusively of peloidal structures. **Riding (1991)** showed that the matrix of thrombolites consists of peloidal crusts which can contain fragments reef organisms. The existence of laminitic microstructures is linked by the presence of stromatolites. They can be composed either of peloids (peloial stromatolites), or from micritic laminae (most likely from microbial activity). Stromatolitic fabrics may occur with thrombolitic fabrics forming structures that can provide a degree of lamination **(Riding, 1991).**

Within the carbonate deposits from Buila-Vânturariţa, it was observed a dominance of thrombolitic-peloidal mesostructures. Associated with these structures appear laminated mesostructures (stromatolites), clotted microstructures and microstructures made of micritic laminae. Stromatolites can contain within their composition encrusting micro-organisms. In terms of macrofabrics, these structures are difficult to observe in the field, in respect to this, the observations and descriptions are limited to the meso-and micro-structures.

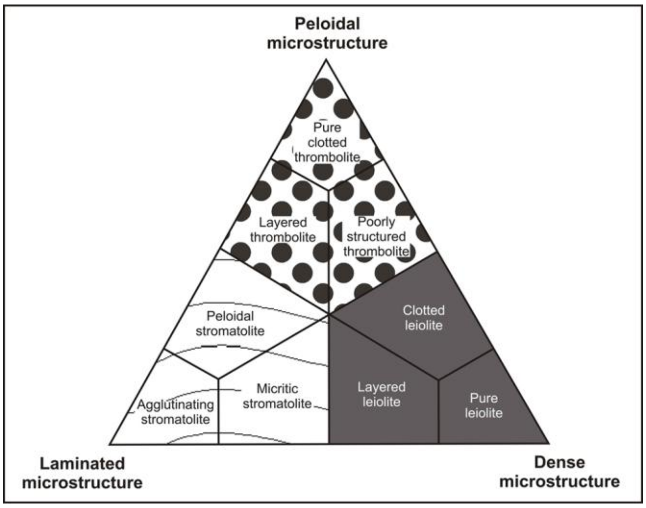

Fig. 11 – The classification of the Mesozoic microbial structures (from **Pleş et al., 2013,** modified after **Flügel 2004**)

CHAPTER 7. Analysis of diagenetic processes.

The diagenetic processes which affect the carbonate rocks mainly relate to: cementation, compaction, dissolution, neomorfism, dolomitization and microbial micritization. These processes can occur simultaneously with the sedimentation (sindepozitional character), continuing into burial environment, or after uplifting and suaerial exposure of the carbonate deposits. The effects of these processes are represented in the form of various types of specific cement types and textures in carbonate rocks, which allows the identification of the diagenetic environments. These are: the marine diagenesis, burial diagenesis environment and the meteoric diagenesis (**Flügel, 2004; Scholle & Ulmer-Scholle, 2003**).

In the Upper Jurassic - Lower Cretaceous limestones of Buila-Vânturariţa, we identified numerous diagenetic processes related to the three main diagenetic environments, especially in the Jurassic reef deposits.

CHAPTER 8. The evolution of the depositional environments during the Upper Jurassic – Lower Cretaceous in the Buila-Vânturarița Massif.

The Upper Jurassic-?Neocomian carbonate deposits (**TMF1, TMF2** and **TMF4**) of Buila-Vânturariţa are mainly composed of reef limestone with massive appearance. In the middle and lower parts of the analyzed successions are found thick levels of reef rudstone intercalated with coral-microbial boundstone. In general, the bioconstructions appear interspersed in succession and are installed or developed on carbonate breccia facies.

The encrusting organisms have played an important role in the development and strengthening of the Jurassic reef framework. They are important elements in deciphering and interpreting depositional environments. The main encrusting organisms are: *Crescentiella morronensis*, *Koskinobullina socialis*, *Lithocodium aggregatum, Bacinella*-type structures, *Radiomura cautica*, *Coscinophragma* sp. and *Troglotella incrustans.* The Upper Jurassic-?Neocomian carbonate deposits can be classified on what has been defined as "coral-microbial-microencruster boundstone" (**Pleș et al., 2013**).

The association of intraclastic-coarse-bioclastic rudstone/grainstone facies with bioconstructions, highlights the external shelf slope environment of a carbonate platform. The vertical evolution of facies associations reveals a gradual shift from the reef slope environments, to the reef crest and indicates the progradation of the carbonate platform during the Upper Jurassic.

In the upper part of the Upper Jurassic-?Neocomian succession are found all terms of peritidal environment (subtidal, intertidal and supratidal).

The distinguishing feature of the high energy subtidal environment is given by grainstone and packstone with coral fragments, large benthic foraminifera, and fragments of dasycaldacean algae. In succession, these limestones are intercalated with micritic subtidal and intertidal deposits. The granular suport and type of carbonate components of these associations, shows a normal marine environment with shallow waters and high energy. Such environments may represent tidal cords or coastal zones of shallow domainsof the carbonate platform (**Ginsburg, 1975, Shinn, 1983a; Hardie & Shinn, 1986; Tucker & Wright 1990; Pratt et al., 1992**).

The subtidal environment with restrictive conditions (**TMF5**) is represented by mudstone/wackestone and packstone with fenestral structures and cyanobacteria oncoids. The oncoid cortices consists of microbial microstructures, rivulariacean type cyanobacteria, *Bacinella*-type structures, *Lithocodium aggregatum* and *Thaumatoporella parvovesiculifera*.

Intertidal environment contains beach deposits formed in areas with high energy (peloidal grainstone with "keystone vugs") and fine laminated deposits, (peloidal packstone), characteristic of a low-energy environment. These limestones are frequently associated with intertidal facies ponds or supratidal deposits. The most representative microfacies are: bioturbated-peloidal mudstone, peloidal mudstone with horizontal lamination, peloidal wackestone with *Favreina* and peloidal-fenestratal mudstone/wackestone. Bioclasts are represented by foraminifera, crustacean coprolites (*Favreina* sp.), bivalves with small and thin shells, gastropods, ostracods and cyanobacteria.

Supratidal environment contains unfossiliferous and fenestrated micritic limestones, which can be dolomitized. Fenestral structures represent characteristic features of the upper intertidal-supratidal environments (**Shinn, 1968a; Lucia, 1972; Shinn, 1983a; 1983b; Tucker & Wright, 1990**).

Lower Cretaceous deposits (**TMF3**) of Barremian-Aptian age developed in Urgonian facies, are found only in the upper part of the carbonate successions of Mount Arnota, Costești Gorges, Cacova Mountain, Mount Albu, Ştevioara and Curmătura Oale sectors. They are transgressively disposed on the top of the Upper Jurassic-?Neocomian deposits. The most important identified species for establishing the age of these deposits are the following foraminifera *Parakoskinollina jourdanensis*, *Paracoskinolina* sp., *Vercorsella camposaurii*, *Nautiloculina broennimanni*, *Pfenderina globosa*, *Pseudolituonella* sp. and *Everticyclammina* sp.

The main microfacies are represented by bioclastic-peloidal wackestone with foraminifera (*Parakoskinolina jourdanensis* and *Vercorsella camposaurii*) and bioclastic packstone with rudist fragments. Diaclases, micritizations and typical microfossils (foraminifera) are the main characteristics of these Cretaceous limestones.

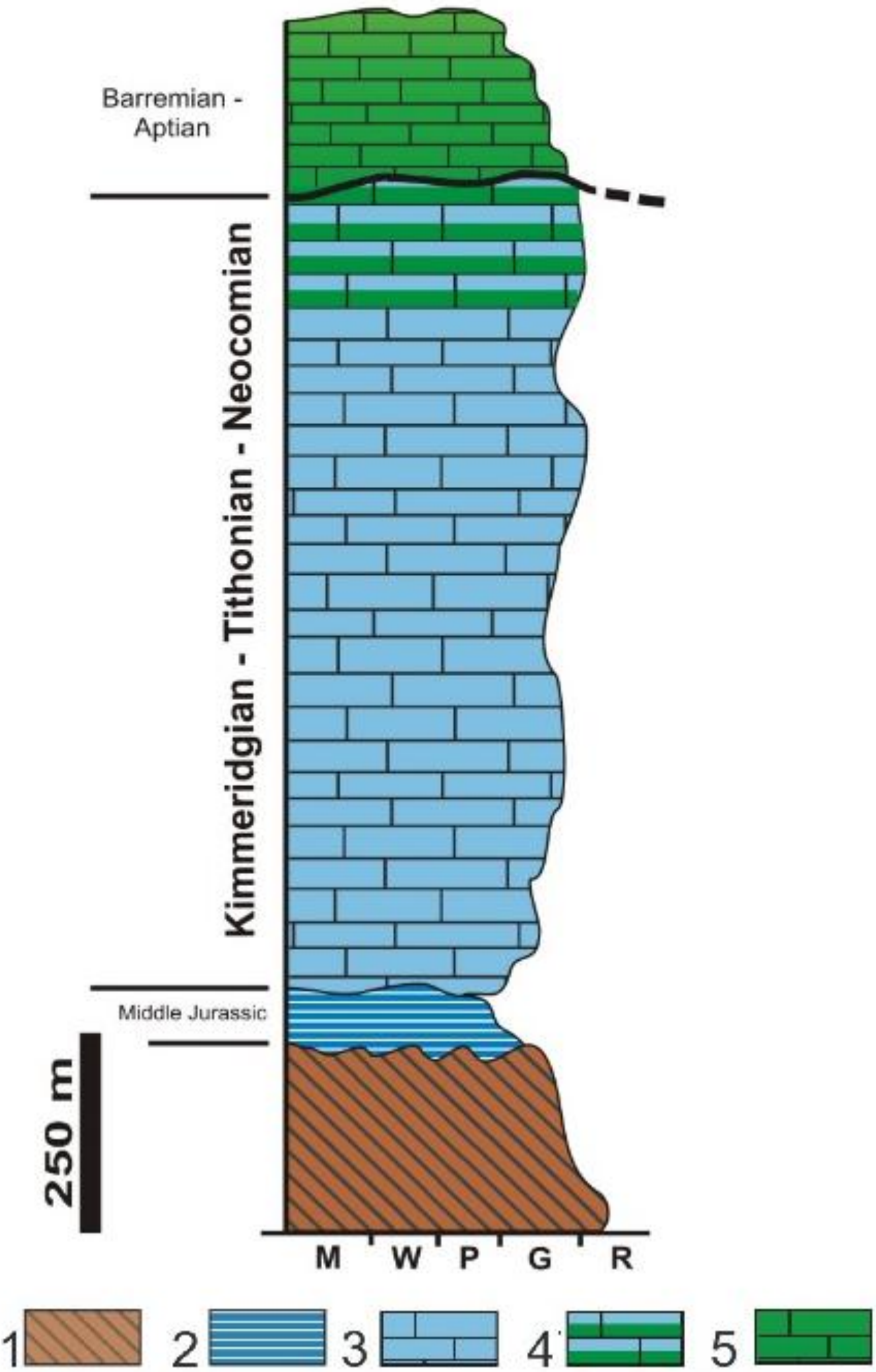

Fig. 12 – General succession of the Buila-Vânturarița deposits: 1 – Metamorphic basement; 2 – Middle Jurassic; 3 – Kimmeridgian-Tithonian coral-microbial bioconstructions; 4 – Neocomian peritidal limestones; 5 – Urgonian type limestones(Barremian-Aptian).

Conclusions

The main objective of this thesis was the detailed study of Upper Jurassic - Lower Cretaceous calcareous deposits of Buila-Vânturariţa Massif in order to identify the microfacies and microfossils, diagenesis processes, interpretation of facies associations and depositional paleoenvironments and establish a general stratigraphic succession. This study highlighted the importance of encrusting micro-organisms and microbial structures in strenghtening the reef bioconstructions from these carbonate deposits.

To achieve this purpose, I have collected a total of 1250 samples of which 1270 were made thin sections. Samples were taken from eight different areas within Buila-Vânturariţa (Bistrita Gorges, Arnota Quarry - Mount Arnota, Costești Gorges, Cacova Mountain, Monastery Pătrunsa - Mount Albu, Schitul Pahomie - Șaua Ştevioara, Schitul Pahomie - Curmătura Oale and Cheia Valley) for petrographic and micropaleontological analyzes.

Microfacies analysis allowed the identification of petrographic and micropaleontological characteristics of the studied carbonate deposits. The identification of microfacies, the main facies associations and microfossils allow us to date the limestones, to interpretate the depositional environments and their integration into a whole peleogeografic context.

This paper brings some new contributions to the knowledge of micropalaeontological associations, especially to the encrusting micro-organisms. The main types of microfacies and microfossils associations have been identified, described and illustrated based on specimens collected from the studied profiles.

The description of coral-microbial boundstone associated with microbial crusts is one of the most important results of our study. This is to contribute to the accumulation of new knowledge on Upper Jurassic reefs of the Intra-Tethyan realm that are poorly documented compared with those on the northern edge of the Tethyian domain.

The presence of the enigmatic micro-organism *Epiphyton* in the Upper Jurassic limestones of Bistrita Gorges, is an important finding given that this organism was known only from Paleozoic. Recently it has been discovered in other Kimmeridgian-Tithonian deposits from Romania and it makes the subject of a study under preparation (**Săsăran et al.,** in preparation). In the samples from Costeşti Gorges and Mount Albu, I have idetified two specimens of *Perturbatacrusta leini* different from those known so far. The new material allows observations on the skeletal structure of this taxa and also integration to the calcareous sclerosponges group (**Pleş & Schlagintweit, 2013**).

The associations of calcareous algae and benthic foraminifera identified in samples from Buila Vânturariţa allowed us to establish the age of the carbonate deposits under study.

The study of microfacies and micropalaeontological associations allowed the interpretation of depositional environments. The Upper Jurassic limestones are dominated by the presence of gravity flows (levels of thick reef rudstone) interspersed with coral - microbial bioconstructions with stromatoporoids and encrusting micro-organisms developed mainly in the form of "patch reefs". Microbial crusts and sindepositional cements, have served to strengthen and binding the reef slope facies. Depositional environment changes towards the top of the succession, gaining main characteristics of the peritidal environment (subtidal, intertidal and supratidal).

We believe that through this paper we contribute to a better understanding of carbonate deposits of Upper Jurassic – Lower Cretaceous from the Buila-Vânturariţa Massif, and thereby improve the overall image of the Mesozoic rimmed carbonate platforms of the Intra- Tethyian domain.

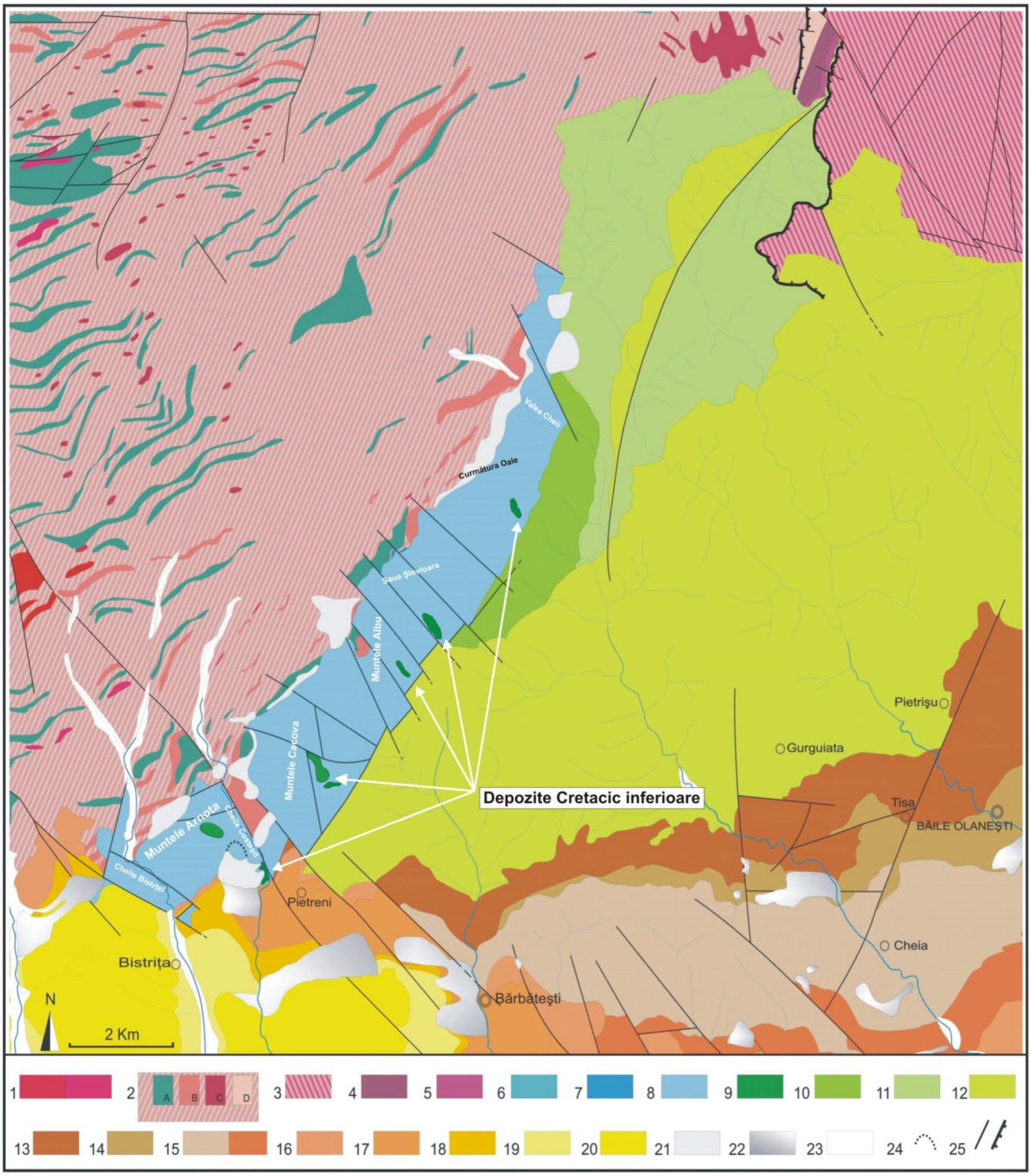

Fig. 13– Geological map of the Buila-Vânturariţa Massif (modified after Lupu et al., 1978); 1-Magmatic rocks; 2-Sebeş-Lotru lithogroup; 3-Cozia lithogroup; 4,5-Triasic; 6-Bajocian-Callovian; 7-Callovian-Oxfordian; 8-Kimmeridgian-Tithonian; 9-Barremian-Aptian; 10-Albian-Cenomanian; 11-Coniacian-Santonian; 12-Campanian-Maastrichtian; 13-Ypresian-Lutetian; 14-Lutetian-Priabonian; 15-Oligocene; 16,17-Lower Miocene; 18-Middle Miocene; 19,20-Upper Miocene; 21,22,23-Quaternary deposits; 24-Arnota quarry;

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