Microfacies of the Emen Formation (Lovech Urgonian Group, Lower Cretaceous, Fore-Balkan)

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Abstract. Detailed microfacial analysis of three sections of the Emen Formation (Lovech Urgonian Group, Central Fore-Balkan) revealed thirteen different facies types corresponding to distinct sedimentary environments on the carbonate platform, such as basin, external and internal platform. Among these, facies types of the internal platform seem to be the most common. The section near the “Al. Stamboliyski” dam differs from the one near Emen village and from a drillhole section (“Preobrazhenski manastir”) because of the diverse compositional structures of the limestones and the large number of shaly-terrigenous intercalations. The upper part of the “Al. Stamboliyski” section is composed of mixed muddy-terrigenous facies types. These characteristics are interpreted as the result of different settings on the carbonate platform in terms of paleogeography, reflecting also changing of the depositional conditions through time. This study, based on the quantified curves of vertical evolution of microfacies associations, provides a key to the temporal and spatial evolution of sedimentation during the deposition of the Emen Formation. The facies types described in this study can be directly compared to those recently defined in the Lower Cretaceous carbonate platform of Southern France.


Key words: microfacies; Lower Cretaceous; Fore-Balkan, Bulgaria

Introduction

The Emen Formation was introduced by Hr. Hrischev (1966) and it belongs to the Lovech Urgonian Group (Хрисчев, 1966; Николов et al., 1991). The formation has its best outcrops in the area between the Osum and Jantra rivers (Хрисчев, 1966). Typically the Emen Formation is made up of different types of micrites, most characteristically Urgonian limestones type (with pachyodontes), biodetritic and organogenic limestones in which the intercalations of shaly
Fig. 1. Sketch map showing the location of the sections of the Emen Formation described in this paper. 1. Urgonian carbonate platform; 2. measured section; 1. drillhole section “Preobrazhenski manastir”; 2. outcrop section Emen; 3a. outcrop section “Al. Stamboliyski” dam, lower part; 3b. outcrop section “Al. Stamboliyski” dam, upper part

or shaly-terrigeneous rocks are relatively rare.

In this work some preliminary results are presented, based on the microfacial analysis of the sediments of the Emen Formation.

Whereas the type area of the formation was defined by Хрисцев (1969) in the region around the village of Emen, the type section is located next to the “Al. Stamboliyski” dam. Хрисцев (1969) also provided a general description of the lithologic characteristics and the most dominant microfacies types. Further results of microfacial analysis in other areas, where the widespread Emen Formation outcrops, made it clear that sedimentation of this unit occurred in a shallow-water environment, well protected from wave-action, suggesting lagoonal deposition with connections to the open sea (Хрисцев, 1969; Хрисцев, Бакалова, 1974).

Methods
The lithologic description of the investigated sections was supplemented by macrofaunal observations. Samples were taken from every 1 m interval along the profiles and whenever there was a marked change in lithology. The thin sections from the samples were studied first by a binocular lupe with polarizator and then by means of a Reichert microscope. The subdivision of rock types were determined using the classification of Folk (1959) and the textural types following the scheme of Dunham (1962). Description of the thin sections also included the qualitative and quantitative analysis of the matrix and the allochems. The quantitative measurements were summarized in terms of percentages following standarized etalon tables (see Bacellie, Bosellini, 1965, in Flügel, 1982). The sizes were measured by micrometer.

The microfacial model of the carbonate platform adopted in this study has been defined by Arnaud-Vanneau (1980), Arnaud-Vanneau, Arnaud (1987, 1994). In fact, the characteristic facies successions described from the Emen Formation in this study were compared to the family facies groups of Arnaud-Vanneau, Arnaud (1987, 1994). The general characteristics of the Emen Formation are shown in vertical profiles (Figs. 1, 2, 3a and 3b). As Arnaud-Vanneau, Arnaud (1994) pointed out, the position of a given facies (or family facies group) in these profiles cannot be tied directly to a paleogeographic environment. Every facies with its typical association of elements reveals the particular characteristics of the environment where it was deposited. In this study the vertical zonation scheme of Perés is adopted (Perés, 1961, in Arnaud-Vanneau, Arnaud, 1987). The construction of curves tracing the vertical evolution of microfacies also allowed the study of temporal and spatial changes in the sedimentary environments (Figs. 1, 2, 3a and 3b). These graphic displays of the studied sections show the proportions of the main allochems and the textures in a quantitative manner.

The observed facies associations reflect different sedimentary environments on the carbonate platform, such as the internal and external platform areas and the basin. The investigated sections of the Emen Formation presented in this paper reveal a specific spectrum of facies displaying small variations in detail. This study describes facies associations reflecting certain environments. The occurrence of mixed facies types, where different facies elements coexisted, seems to be fairly typical. This fact can be explained in terms of interplay between environmental factors such as light, temperature, sediment dynamics and depth. The interpretation of these factors, however, falls beyond the scope of this paper.

Geologic setting of the studied sections
This study is based on the analysis of three sections of the Emen Formation: a drillhole section named “Preobrazhenski manastir”, an out-
Fig. 2. A, Section of the Emen Formation in drillhole section "Preobrashenski manastir". B, Textural types of carbonate rocks after Dunham (1957) and quantitative distribution of allochems. C, Curve illustrating the vertical evolution of microfacies, for legend see Fig. 3C.
crop section near Emen village and another outcrop section near the “Al. Stamboliyski” dam.

Drillhole section, “Preobrazhenski manastir”

This well was drilled on a mesa composed of massive limestones, above the Preobrazhenski monastery, to the NW of Veliko Tarnovo. The total depth of the well was 62.8 m, encountering the middle and lower parts of the Emen Formation and the uppermost part of the underlying Balgarene Formation (Fig. 1). The bottom of the Emen Formation is located at 59.0 in the well.

Just below this contact the Balgarene Formation is composed of a marly unit, whereas downwards it is made up of carbonates. The marl itself has a grayish-blue colour and it contains pyrite and irregularly disseminated biodetritus. The carbonate unit is characterized by a shaly, oolitic limestone with biodetritus and intraclasts, whereas the reddish brown, shaly matrix has numerous small-sized and therefore undetermined biodetritus in it.

The Emen Formation has a very monotonous character in this well, it is composed of a limestone which has a light blue to white colour on weathered surfaces and a light brown colour on fresh surfaces. Pachyodont remnants are common almost through the whole succession, either in the form of the whole shell or as its fragments. Only in the lowermost and uppermost parts of the well was yellowish colour observed on the weathered surfaces of the oolitic and coarse biodetritic limestone.

Outcrop section, near Emen village

This section is exposed to the North of village Emen, in the gorge of the Negovanka River. In this outcrop the limestones with Pachyodonts and a predominantly bluish color on weathered surfaces and a light brownish, beige colour on fresh surfaces. The limestone has a massive, thick-bedded character with occasionally a nodular texture. At this locality the lower and middle parts of the Emen Formation are exposed (Fig. 2), although the lower boundary of the formation cannot be observed.

Outcrop section, “Al. Stamboliyski” dam

This section is located on the northwestern slope of the “Haidut tepe” hill. The lower part of the section (Fig. 3a) is located some 200 m to the S. from the wall of the dam and follows the road from G. Kosovo to Kramolin. The upper part of the section (Fig. 3b) begins at the southern edge of village G. Kosovo, at the bridge through the Rosica River and it follows the road to the North towards Pavlikeni. Concerning the outcrop at the wall of the “Stamboliyski” dam, it represents the upper part of the Emen Formation, situated above the Magarski wedge of the Balgarene Formation (Xрисчен, 1966). The lower and upper boundaries of the Emen Formation cannot be observed at this locality. The section is made up of compositionally and texturally very diverse limestones. Shaly-terrigenous intercalations are quite common. The upper part of the section is characterized by mixed carbonate-terrigenous facies units.

The above sections span very different levels of the Emen Formation. Only the drillhole section “Preobrazhenski manastir” and the outcrop section near village Emen may overlap in a chronostratigraphic sense. Therefore the correlation between these two sections can be attempted.

Chronostratigraphic framework

The Barremian/Aptian boundary was placed in the Lovech Urgonian Group, within the Emen and Balgarene Formation by Xрисчен (1966), Николов (1969) and Ковачева (1979). This means that the sediments of the Emen Formation are partly Late Barremian and partly Early Aptian in age.

On the basis of recent ammonite findings Ivanov, Nikolov (1995) refined the age of the Lovech Urgonian Group: its lower part is Early Barremian, its middle part is Late Barremian and its upper part is Early Aptian in age.

Description of microfacies of the Emen Formation

The following facies types were established:

— Microfacies types of the basin. Circalittoral environment:
  * Pelmicrite with fine biodetritus
  * Biopelmicrite with bryozoa, rounded algae fragments, annelids, large agglutinated foraminifera, Lenticulina, Neotrocholina, Melathrokeria, Choffatella
— Microfacies types of the external platform Circalittoral-Infracalittoral environments:
  * Biopelmicrite to biopelmicracsparite with poligenic, unsorted biodetritus and Everticyclamina
  * Biomicrite to biosparite with bryozoa, echiroids and poligenic biodetritus
  * Biomicrite to biomicracsparite with coarse, rounded biodetritus, intraclast and pellets
  * Biomicrite to biosparite with coarse, rounded biodetritus, oolites and pellets
Fig. 3. A, Outcrop section of the Emen Formation near Emen village. B, Textural types of carbonate rocks after Dunham (1957) and quantitative distribution of allochems. C, Curve illustrating the vertical evolution of microfacies. Legend: M, mudstone; w, wackstone; p, packstone; g, grainstone; b, boundstone; 1, small foraminifers; 2, large foraminifers; 3, orbitolinids; 4, solitary corals; 5, colonial corals; 6, hydrozoa; 7, chetetidae; 8, Bacinella; 9, Dasycladacea; 10, gastropods; 14, oysters; 15, brachiopods; 16, echinoids; 17, bryozoa; 18, detritus; 19, intraclasts; 20, oolites; 21, pellets; 22, silt; 23, sand; 24, marl; 25 silty sandstone.
— Microfacies type of the rim of the carbonate platform
  * Oosparite
  * Oobiosparite with coarse, well rounded bioclasts, pachyodonts, solitary corals and terrigenous-clastic minerals

— Microfacies types of the internal platform.

Infralittoral environments:
— Microfacies types of the external part of the internal platform:
  * Biomicrite with corals, finegrained bioclasts, *Lithocodium*, encrusting sponge
  * Biomicrite to biomicrosparite with pachyodonts, dasycladacea, *Bacinella*, pellets and large foraminifera
  * Biopelmicrite to biopelsparite with pachyodonts, small foraminifera, biodetritus and *Salpingoporella*
  * Biopelmicrite and biopelsparite with variable-sized, micritized biodetritus, pellets, small foraminifera, rare oncolits and *Bacinella*
  * Pelmicrite with pachyodonts and *Bacinella*

— Microfacies types of the internal part of the internal carbonate platform. Medio- and supralittoral environments:
  * Biomicrite to biosparite with fine, micritized biodetritus, pellets, oncolits and *Miliolidae*

Description of microfacies of the Emen Formation

Microfacies types of the basin. Circalittoral environment

**Pelmicrite with fine bioclasts**

This facies displays the characteristics of the family facies F2 (Biopelmicrites a spatangides) described by Arnaud-Vanneau, Arnaud (1987, 1994).

Macroscopic characteristics. Nodular, shaly limestone, which has a bluish colour on fresh surfaces. Thin marly intercalations are frequent. The macrofauna is represented by small-sized, irregular echinoid and bivalve fragments.

Microscopic characteristics. This limestone is a pelmicrite with fine biodetritus. Texture: mudstone-wackestone. The matrix is micritic, composed of fine, strongly fragmented and unrounded biodetritus, terrigenous clastic material, pellets, pelletoids and foraminifers. This rock is unsorted.

The quartz content varies between 5 and 10%. The average grain size of unrounded terrigenous quartz particles is 0.003 mm, whereas the maximum size is 0.009 mm. The pellets are oval-shaped micritic particles with well-defined outline. The pelletoids have irregular shape without a sharply defined outline. The pellets and the pelletoids make up 3 to 10% of the rock volume. The pelletoids, regardless their larger size on average, make up only a very few percentage of the rock volume.

The macrofauna is both allochthonous and autochthonous. Due to the generally low degree of preservation the macrofauna is undeterminable. It contains, however, small-sized, unrounded echinoid fragments, rarely bryozoa, bivalve, gastropode, brachiopode and rounded *Codiacea* algae fragments.

The foraminifera association is represented by circalittoral and infralittoral forms: *Lenticulina, Everticyclammina, Textularia, Tristix, Neotrocholina*. A subtype of the above described facies can be also defined:

**Biopelmicrite with bryozoa, rounded algae fragments, annelids, large agglutinated foraminifera, Lenticulina, Neotrocholina, Melathrokerion, Choffatella.**

In this subfacies the matrix is micrite, in part irregularly recrystallized to microsparite. Only locally sparitic cement was observed. The maximum quartz content of this facies is 15%. The fauna is richer than the above listed organisms also containing rounded, superficially micritized fragments of algae (e.g. *Boueina*). The foraminifera association includes: *Choffatella, Everticyclammina, Textularia, Neotrocholina, Conorboides, Lenticulina, Melathrokerion, Charentia*.

This facies in some respects differs from the previous one:
a) Larger amount of detritus (up to 29%), which is mostly present as unrounded fragments derived from molluscs, bryozoa and algae;
b) Higher percent of oval-shaped, small-sized pellets (up to 12%);
c) Larger amount of quartz, ranging up to 15%;
d) Richer foraminifera association;

The sediments of the formation in the upper part of the section at the “Al. Stamboliyski” dam were deposited in the circalittoral zone (Tabl. 1, 2).

Microfacies types of the external platform. Circalittoral and Infralittoral environments

These facies types are characteristic for the slope and the upper part of the external slope of the platform. These environments correspond to the circalittoral and infralittoral zones. As compared to the facies types of the basin, these slope facies types are different in several respects:
a) High percentage and large size of bioclastics. These clasts are dominantly coarse, low to
moderately rounded, reworked fragments of the macrofauna;

b) Superficial micritization of the biodetritic component;

c) Relatively low percentage of terrigeneous clastics;

**Biopelmicrite to biopelmicrosparite with poligenetic, unsorted biodetritus and Everticyclammina**

This facies type is comparable to that of the family facies F3 (Biopelsparites a debris d’echinodermes et petits foraminiferes) of Arnaud-Vanneau, Arnaud (1987, 1994).

**Macroscopic characteristics.** The limestone is thin- to medium bedded, at certain levels with nodular textures. Thin marly intercalations are frequent. On fresh surfaces the limestone has a bluish colour.

**Microscopic characteristics.** Biopelmicrite to biopelmicrosparite with poligenetic, unsorted biodetritus. The texture is a wackestone-packstone.

The micritic matrix makes up about the 60% of the rock. The biodetritus content can reach locally the 35% and it can be subdivided into two clearly defined fractions:

a) The smaller part of the first, autochton fraction is made up of unrounded biodetritus with undeterminable elements due to the dissolution of the original organogenic structures. These elements were most probably bivalves, gastropods and brachiopods. The bigger part of the fraction, however, is made up of unrounded fragments of echinids, bryozoa, bivalves, brachiopods and anelides, still showing the original organogenic structures of these organisms.

b) The coarse, allochthonous fraction displays the characteristics of reworking by lateral transport in a moderate hydrodynamic system. This fraction is mainly composed of coarse, superficially micritized, moderately- to well-rounded fragments of corals, bivalves, gastropodes and algae. A part of the macrofauna is characterized by completely dissolved organogenic structure. Some of these fragments have been finely incrustated mostly by Lithocodium and less typically by Bacinella. Most probably these elements have been formed at the rim of the carbonate platform and they were subsequently transported by currents on the slope.

The oval-shaped pellets have an average size of 0.009 mm and they make up the 10-12% of the rock.

The foraminifera association of this facies includes the following taxa: Everticyclammina, Neotrocholina, Conorboides, Charentia, Lenticulina, Mililoidae, Textulariidae. The occurrence of large, agglutinated foraminifers is the most common (mainly Everticyclammina). Other genera, such as Lenticulina can be observed only occasionally and it is typically very poorly preserved.

The mineral fraction (mostly quartz) makes up about the 2.5% of the rock.

The above described facies was established based on the outcrop section of the “AI. Stambolyski” dam and the drillhole section “Preobrazhenski manastir” (Tabl. I, 3).

**Biomicrite to biomicrosparite with bryozoa, echinoids and poligenetic biodetritus**

This facies fulfills the criteria given by Arnaud-Vanneau, Arnaud (1987, 1994) for their F4 family facies (Biosparites and biomicrites a Bryozaries et Crinoïdes). The only difference is that in the Emen Formation the elements are more rounded, the foraminifera association is more abundant and it shows a bigger taxonomic diversity and the crinoidea fragments are relatively rare.

**Macroscopic characteristics.** A medium-bedded (30-40 cm thick) limestone alternates with thin, marly beds. On fresh surfaces the limestone has a redish colour and the biodetrital texture is not very pronounced.

**Microscopic characteristics.** Biomicrite to biomicrosparite and biosparite with bryozoa, echinoidea and poligenetic biodetritus, the texture is a packstone.

The matrix makes up 45-55% of the rock and it is a partly recrystallized micrite, locally with granular cement. The other, about 50% of the rock volume is composed of biodetritus, pellets, intraclasts, oncoids of Bacinella, terrigeneous clastic material, foraminifers.

The biodetritus is made up of poorly rounded and poorly sorted elements with variable degree of preservation. Among these are commonly found elongated fragments of bivalves, gastropodes, encrusted by algae (Boueina) and more isometric fragments of bryozoa, echinoids and crinoids. The unevenly micritized fragments of dasyclades (mostly Salpingoporella and Cylin­droporella) are less common. Sporadically single nodules of Bacinella can also be observed. The nuclei of these nodules are large, rounded bioclasts whose original organogenic structure is completely destroyed and replaced by a mosaic of coarse-grained calcite. These Bacinella nodules were described by Arnaud-Vanneau, Arnaud (1994) as characteristic elements for the external parts of the internal platform (facies F8) from where they were reworked.

About 60% of the bioclastic component is irregularly micritized.
The pellets are typically observed as oval-shaped and isometric micritic particles. They make up about 3-12% of the rock. The volume of clastic component (quartz) is about 0.5% on average and its maximum value does not exceed 5%. The grains are unrounded and have an average grain size of 0.03 mm.

The foraminifera association includes the following taxa: *Neotrocholina*, *Pseudocyclammina* (?), *Derventina*, *Quinqueloculina*, *Textularia*, *Cuneolina* (?), and singular forms of *Lenticulina*.

This microfacies is analogous in terms of fauna and flora to group D (noyau D) of Peybernès et al. (1979) and therefore it is considered as being typical for the circalittoral and external infralittoral zones, characterized by middle to moderate energy conditions.

This microfacies is present in the upper part of the outcrop section at the “Al. Stamboliyski” dam (Tabl. 1, 4).

**Biomicrite to biomicrosparite and biosparite with coarse, rounded biodetritus, intraclasts and pellets**

This facies seems to be the equivalent of the F5 family facies (Biosparites a gros debris subsphaeriques) in the scheme of Arnaud-Vanneau, Arnaud (1987, 1994).

Macroscopic characteristics. The medium-bedded (40 cm thick) to massive limestone has a light-brown to grayish colour on weathered surfaces whereas it is cream coloured on fresh surfaces. The texture of the limestone is coarse biodetrital, due to the large volume of coarse fragments of macrofauna such as bivalves (mostly *Ostrea*), brachiopods (Rhynchonellida), fragments and nodules derived from colonial and branching corals.

Microscopic characteristics. Biomicrite to biomicrosparite and biosparite with coarse, rounded fragments of corals, spongea, crinoidea, echinoidea, bivalvia, strongly fragmented dasyclades, foraminifers, pellets and intraclasts. The texture is a packstone-grainstone.

The matrix, which makes up about 45% of the rock, is mostly composed of micrite. Locally the matrix has been irregularly recrystallized to microsparite. Only in a few places can be observed drusy cement.

The bioclastic component (up to 38%) is made up of very mixed associations. Two associations can be distinguished. One of these includes coarse fragments of echinoids, crinoidea, dasyclades, bivalves, corals, bryozoa with an average grain size of 0.2-0.5 mm. The maximum size of these fragments is about 6 mm. The other association is composed of smaller fragments of algae and bivalves. The bioclastics are dominantly micritized, in an irregular fashion. Some fragments, such as solitary corals and bivalves, have lost completely their original organogenic structure.

The rock also has a relatively large volume (up to 15%) pellets, micrites and microsparitic particles with an irregular shape.

The percentage of intraclasts varies between 1 and 10%, with rounded, well defined shape. The micritic matrix has small-sized, unrounded biodetritus.

The amount of clastic terrigenous material in the matrix is almost negligible, ranging from 0 to 2.5%. At certain levels reworked, oval-shaped oolites can be observed, with one or two concentrical layers around the nucleus.

The abundance of large agglutinated foraminifers (mostly *Everticyclammina*), highconical orbitolines and fragments of algae *Codiaceae* (*Boueina*) and *Dasycladacea* (*Salpingoporella*) is very typical for this facies. Other foraminifers, such as *Neotrocholina*, *Quinqueloculina*, *Lenticulina*, *Textularia*, *Haplophragmoides*, *Valvulineria* can also be found.

Subfacies of the above described facies can be defined on the upper slope of the carbonate platform:

**Biomicrosparite and biosparite with coarse, rounded biodetritus, oolites and pellets**

Macroscopic characteristics. The medium-bedded (30-40 cm thick) limestone has a grayish-bluish colour on weathered surfaces and the texture is coarse biodetrital.

Microscopic characteristics. Biomicrosparite and biosparite with oolites, coarse and rounded biodetritus, large agglutinated foraminifers, *Cy­lindroporella*. The texture is a packstone-grainstone.

The facies is identical to the one described above, the only difference being the mainly microsparitic (subcrystallic) type matrix. Almost all the particles have a small core composed of drusy calcite and locally coarse sparitic cement can be observed. Large oolites with concentric structure can be also observed.

The oolites make up 20 to 35% of the rock. The core of oolites is composed of very fine layers in a concentric geometry. Only a few of the oolites have a recrystallized core with radial pattern in it. The nucleus is always made up of an organogenic fragment. Commonly the shape of the oolite is rounded, but occasionally they have an oval-shaped or elongated and some of them are compound oolites.

The biodetritus is composed of rounded, coarse fragments. The same fragments can be
observed more or less within the internal part of the oolites. These are elongate, well-rounded fragments of bivalves, brachiopods, algae (Codiaceae), echinoids and bryozoa. Also dasycladae algae (Cylindroporella, Terquemella) occur. Less frequent are fragments of corals encrusted by Lithododium or sponges. Both high- and low-conical gastropods can also be found.

Part of the biodetritus is superficially micritized. The terrigenous clastic content (about 1%) is represented by unrounded fragments of quartz with an average grain size of 0.006 mm. The rock is itself unsorted.

This facies most probably can be assigned to the F5-6 family facies of the Arnaud-Vanneau, Arnaud-scheme. The character of the fragments and the matrix and the degree of sorting indicate that these sediments were deposited in the infra- littoral zone, under high-energy conditions.

This facies was found in all the studied sections (Table II, 1,2).

Microfacies types of the rim of the carbonate platform

Oosparite

Macroscopic characteristics. The limestone is thin-bedded and it has a yellowish-brown colour on weathered surface.

Microscopic characteristics. Biomicr sparite and biosparite with oolites, coarse and rounded biodetritus, large agglutinated foraminifers, Cylindroporella. The texture is that of a grainstone.

The matrix is generally sparite cement, making up 38-40% of the rock. On most of the fragments a certain encrustation can be observed. The rock is very well sorted, somewhat opaque and compact. The oolites (about 47%) actually provide the frame of the rock. Their shape is rounded or oval/elongated with a commonly small-size of 0.2 mm, rarely up to 0.3 mm. The internal structure of the core of the oolites displays radial concentric structure. The compound oolites show the same characteristics.

The poligenetic, small-sized biodetritus, such as crinoids, dasyclades, bryozoans, spongea form either the nucleus of the oolites or they are dispersed within the matrix. A part of the biodetritus is incompletely micritized.

Foraminifers are rare, but occasionally Haplophragmoids, Bolivinopsis(?), Cuneolina(?) and Pseudocyclammina can be found.

The intraclasts (about 5%) are 1.1-5 mm in size and also have a well-rounded and well-defined shape. Small clastic particles are also included and they are linked with the matrix.

The terrigenous clastic content (mostly quartz) is about 4%. The average size of the iso-
assigned to this facies were found in the outcrop section at the “Stamboliyski” dam (Tabl. II, 4).

Microfacies types of the internal platform

**Microfacies types of the external part of the internal platform. Infralittoral environment**

*Biomicrite with corals, finegrained biodetritus, Lithocodium, encrusting spongea*

This type of sediment probably deposited in the infralittoral zone of the back-reef part of the carbonate platform and the external part of the internal platform. The facies can be best correlated with the F7-8 family facies of Arnaud-Vanneau, Arnaud (1987, 1994).

Macroscopic characteristics. Nodular limestone with organogenic, biodetrital texture. The macrofauna is represented by colonial corals, bank-building oysters, solitary corals, undeterminable bivalves and brachiopods.

Microscopic characteristics. Biomicrite with corals and multisized biodetritus. The texture is a wackestone.

The matrix is micritic, composed of unsorted and very fragmented, fine biodetritus (shells of bivalves, brachiopods, gastropods, ostracods). The coarse, unrounded fraction includes fragments of bivalves and algae (*Caye.xia*), corals, pachyodonts and echinoids. The pachyodont fragments still show the original organogenic structure of the shell, perforated by unicellular algae or bacteria and frequently encrusted by *Lithocodium*. The small-sized fraction is partly or completely micritized to an undeterminable mass of biodetritus.

The foraminifera association includes different *Miliolidae* taxa (generally *Quinqueloculina*), rarely *Arenobulimina, Pfenderina, Neotrocholina, Charentia, Choffatella, Melathrokerion, Cuneolina (?), Textularia, orbitolinids and *Paleodictioconus (?)*.

A number of algae were also determined such as *Suppilulimaella, Cylindroporella, Salpingoporella(?), Pseudoactinoporella, Bouenia* and *Caye.xia*.

This facies types is analogous to F8 (Biosparites a biomicrites a gros foraminifers et grands rudistes) of the Arnaud-Vanneau, Arnaud’s (1987, 1994) scheme. According to this authors the sediments within this microfacies were deposited in the infralittoral zone, in a shallow-water environment which was connected to open sea. This facies was also found in all of the studied sections (Table III, 2).

*Biopelmicrite to biopelsparite with pachyodonts, small foraminifera, biodetritus and Salpingoporella*

This facies type can be correlated with the F8-9 family facies of the Arnaud-Vanneau, Arnaud (1987, 1994)- scheme.

Macroscopic characteristics. This massive limestone has a cream-like colour on both weathered and fresh surfaces. The macrofauna is represented by pachyodonts, hydrozoa, spongae and chetetidae.

Microscopic characteristics. Biopelmicrite and biopelsparite with pachyodonts, dasycladaceae, echinoids, *Bacinella* and large agglutinated foraminifers. Sorting cannot be observed and the texture is a packstone.

The frame of the rock is made up of well calibrated pellets, micritized detritus and rarely intraclasts. The texture is a packstone.

This facies can be best correlated with the F7-8 family facies of Arnaud-Vanneau, Arnaud (1987, 1994)- scheme.

Macroscopic characteristics. This massive limestone has a cream-like colour on both weathered and fresh surfaces. The macrofauna is represented by pachyodonts, hydrozoa, spongae and chetetidae.

Microscopic characteristics. Biopelmicrite and biopelsparite with small foraminifers pellets, micritized detritus and rarely intraclasts. The texture is a packstone.

The frame of the rock is made up of well calibrated pellets, micritized detritus, foraminifers and intraclasts. Probably the original micritic
Explanations of the plates

PLATE I

1. Sandy pelmicrite with fragments of bivalve shells (bv), brachiopods (bh), bryozoa (bz) and echinoids (eh). The matrix of this mudstone is micritic (about 80%), the rest of the unsorted rock is composed of fine, strongly fragmented and unrounded bioclasts (9%), terrigeneous clastics (2,5%), pellets and pelletoids (about 8%) and foraminifers. The macrofauna is allochthonous. The microfauna is represented by infra- to infralittoral foraminifers, such as Miliolidae, Everticyclammina, Lenticulina, Triasix, Neotrocholina. Emen Formation, Upper Barremian-Lower Aptian, outcrop section, “Al. Stamboliyski” dam, bottom of the upper part of the section, at 6.8 m; thin section GK-11.

2. Sandy biopelmicrite with rounded fragments of algae, annelids (an), large agglutinated foraminifers, Lenticulina, Choffatella. The matrix of this wackestone is partially micritized in an uneven manner to microsparite. The volume of the bioclastic component is about 10%. The terrigeneous component (10%) is represented by rounded quartz grains with an average grain size of 2.5 mm. Pellets are also present (2.5%) in the form small-sized, oval-shaped and micritized particles. This rock is sorted, with an allo- and autochthonous macrofauna composed of unrounded fragments of fine-shelled molluscs, echinoids, bryozoa and rounded, elongated fragments of algae (Boueia). The microfauna includes Lenticulina, Neotrocholina, Choffatella, Everticyclammina, Textulariidae. Emen Formation, Upper Barremian-Lower Aptian, outcrop section, “Al. Stamboliyski” dam, middle of the upper part of the section, at 18.3 m; thin section GK-25.

3. Biopelmicrosparite with poligenetic, various-sized bioclasts, echinoids (eh), Everticyclammina. The matrix of this wackestone/packstone is a microsparite containing a large amount (22%) of rounded to poorly rounded fragments of echinoids (eh), gastropods (g), fine-shelled bivalves (bv) and annelids. In the lower right corner of the photo a reworked fragment of a coral can be seen, encrusted by Lithocodium. This unsorted rock has the following microfauna: Everticyclammina, Choffatella, small-sized Miliolidae, Textulariidae and Lenticulina. Emen Formation, Upper Barremian-Lower Aptian, outcrop section, “Al. Stamboliyski” dam, middle of the upper part of the section, at 23.5 m; thin section GK-25.

4. Biomicrite to biopelmicrite with pellets, algae, echinoids and poligenetic bioclasts. The macrofauna of this unsorted packstone includes incompletely micritized fragments of algae with rounded cores such as Boueina (bo), Cylindroporælla (cl) and Salpingoporella, bivalves (bv), gastropods (g) and echinoids. The microfauna is represented by common forms of Miliolidae (ml), Textulariidae, Derventina (dv), Neotrocholina and Chofatella (ch). Emen Formation, Upper Barremian-Lower Aptian, outcrop section, “Al. Stamboliyski” dam, upper portion of the upper part of the section, at 28.75 m; thin section GK-35.

5. Biomicrite to biomicrosparite with coarse bioclasts, intraclasts and pellets. This packstone is fragment-supported. All the allochems display a high degree of reworking and rounding. The macrofauna is dominantly allochthonous and includes of coarse, well-rounded fragments of corals, spongæ, crinoids, bryozoa, echinoids (eh), gastropods, bivalves (bv), algae-dasycladacea (Salpingoporella?, sa) and codiacea (Boueina, bo). Almost all of them are superficially micritized. The microfauna is characterized by the dominance of Everticyclammina (ev), but other forms such as Neotrocholina, Quinqueloculina, Conorboides, Haplophragmoides, Valvulineria can also be found. Emen Formation, Barremian-Aptian, drillhole section, “Preobrazhenski manastir”, 3.74 m; thin section PM-2.

6. Biooomicrosparite and biosparite with coarse, rounded bioclasts, oolites (o) and pellets. This packstone/grainstone has a predominantly microsparitic, recrystallized matrix. Almost around all of the allochems a a thin layer of drusy calcite can be found. The oolites (20%) are round- or less frequently oval-shaped and they have a nucleus made up of organogenic particles, surrounded by a multiconcentric structure. The bioclastic component (30%) is composed of rounded fragments of bivalves, brachiopods, algae, echinoids, bryozoa, corals and gastropods. The foraminifera association is poor and it includes mainly large, agglutinated forms and Neotrocholina. Emen Formation, Barremian-Aptian, outcrop section, “Al. Stamboliyski” dam, lower portion of the upper part of the section, 11.25 m; thin section GK-18.
PLATE II

1. Oobiosparite with echinoids, crinoids (cr), bryozoa, bivalves, gastropods and intraclasts (in). This grainstone has a sparitic cement. Around all the allochems crystallization can be observed. Oolites provide the frame of the rock and make up 47% of the volume. They have a multiconcentric, recrystallized radial oolitic cores. The microfauna includes rare *Haplophragmoides* and *Cuneolina (?)* forms. Emen Formation, Barremian-Aptian, drillhole section, “Preobrazhenski manastir”, 1.0 m; thin section PM-1.

2. Sandy oobiosparite with rounded fragments of corals, pachiodonts, incomplete oolites (o). In this grainstone the matrix is composed of a sparitic cement with unequally sized grains and locally dispersed microsparite. The volume of oolites is fairly significant, up to 34.5% on average. They are superficial, in the initial stage of oolitization. Their nucleus is composed of unrounded quartz grains. The biodetritus fragments have a very close size and they are typically well-rounded. The macrofauna is represented by corals, pachiodonts, various bivalves, sponges and echinoids. Some of these fragments are perforated and superficially micritized. The microfauna includes large agglutinated foraminifers, orbitolinids and Neotrocholina. Emen Formation, Barremian-Aptian, outcrop section, “Al. Stamboliyski” dam, middle portion of the lower part of the section, 23.3 m; thin section XT-25.

3. Micrite with corals, fine biodetritus, *Lithocodium*. This mudstone/boundstone has a micritic matrix with unsorted and strongly fragmented biodetritus (bivalves, brachiopods, gastropods and ostracods). The rock-volume is dominated by coral fragments coated by *Lithocodium*. The microfauna includes undetermined ostracods. Emen Formation, Barremian-Aptian, drillhole section, “Preobrazhenski manastir”, 45.94 m; thin section PM-41.

4. Biomicrite with corals, *Bacinella*-nodules, pachiodonts, dasycladacea, echinoids and pellets. This packstone has a micritic matrix which was partially and irregularly recrystallized to microsparite. The rock is fragment-supported. On this photo mostly small-sized fragments of bivalves (bv), algae, such as partially or completely micritized dasycladacea (al), small foraminifers and orbitolinids can be observed. The microfauna includes forams/orbitolinids (or), small-sized Miliolidae (ml). Emen Formation, Barremian-Aptian, drillhole section, “Preobrazhenski manastir”, 33.98 m; thin section PM-31.

5. Biopelmicrite with small foraminifers, pellets, micritized biodetritus, *Bacinella*, occasional fragments of echinoids. This packstone has a micritic matrix partially recrystallised to microsparite. The frame of the rock is supported by small foraminifers, such as Miliolidae (ml), Textulariidae (tx), Arenobulimina, Neotrocholina and others. While pellets account for about 15% volume of the rock, whereas micritized biodetritus for about 10%. Emen Formation, Barremian-Aptian, outcrop section, “Al. Stamboliyski” dam, bottom of the lower part of the section, 0.15 m; thin section GK-1.
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PLATE III

1. Biopelmicrosparite and biopelsparite with small foraminifers, micritized biodetritus, pellets, oncoliths (on) and Bacinella. The original micritic matrix in this packstone/grainstone recrystallized to microsparite in some parts and the original pore space is full of with coarse mosaic calcite. This rock is dominated by micritized biodetritus, pellets and small foraminifers. Because of the strong micritization, the degree of roundness of the bioclastic fragments cannot be determined. In the upper right corner of the photo an oncolith can be observed with a supposedly coralfragment nucleus. The original organogenic structure composed of mosaic calcite is completely destroyed. The core of the oncolith is coated by Bacinella forming a second microgranular layer without any clear laminated structure. The foraminifera fauna is very rich, but the dominant forms belong to the Miliolidae (ml) group. Other forms (not shown in this photo) include different forms of Textulariidae, Sabaudia, Arenobulimina, Cuneolina(?). Emen Formation, Barremian-Aptian, outcrop section, “Al. Stamboliyski” dam, upper portion of the lower part of the section, 68.8 m; thin section XT-52.

2. Biopelmicrite with pachiodonts (ph) and Bacinella. The matrix is micrite. Texture: wackestone/packstone. The detritus is coarse, without any traces of roundness. The shell fragments of the pachiodonts have a different degree of preservation. These fragments were first perforated by endolithic algae and later they were encrusted by Bacinella. Emen Formation, Barremian-Aptian, outcrop section, “Al. Stamboliyski” dam, upper portion of the lower part of the section, 9.4 m; thin section XT-13.

Infralittoral and mediolittoral zone. Internal platform. Inner part of the internal platform.

3. Pelmicrosparite and pelsparite with oncoids (on), small foraminifers, micritized biodetritus, and Bacinella. The original micritic matrix in this packstone recrystallized partially and unevenly recrystallized to microsparite. In some parts the original pore space is full of with sparitic cement. The frame of the rock is supported by oval-shaped pellets, micritized detritus and small foraminifers. In the lower half of the photo an oncolith can be observed. The nucleus is made up by a strongly perforated pachiodont fragment, the core is microgranulated with a laminated structure. Emen Formation, Barremian-Aptian, drillhole section, “Preobrazhenski manastir”, 11.45 m; thin section PM-16.

4. Organogenic limestone. This mudstone/boundstone has a micritic matrix with a large number of small-sized, oval-shaped pellets, terrigenous clastics (about 4%) and ostracods (os). In the lower right and in the upper left corners of the photo fragments of colonial corals can be seen covered by Lithocodium. In the center one can observe a planktonic foraminifera section with very well preserved internal organogenic layers. Emen Formation, Barremian-Aptian, drillhole section, “Preobrazhenski manastir”, 55.18 m; thin section PM-55.

5. Biosparite with bryozoa (br), coarse, poligenetic biodetritus, intraclasts and oolites (o). The matrix of this grainstone is composed of coarse sparitic cement. The biodetritus is mainly coarse and rounded, about 15% is partially micritized with clear indications of reworking and transport. The oolites are oval-shaped, small and have one or two radially recrystallized cores. The nucleus is typically formed by quartz grains with an average size of about 0.025 mm. The quartz content of the rock is about 7.5%. The macrofauna includes bivalves, reworked and rounded fragments of corals, echinoids, crinoids and algae. The microfauna is represented by Neotrocholina. Emen Formation, Barremian-Aptian, outcrop section, Emen, 42.65 m; thin section E-41.
matrix was partly recrystallized unevenly to microsparite and sparite.

Oval-shaped and uniform sized (0.1 mm) pellets form up to 25% of the rock.

The detritus is predominantly small-sized and undeterminable because of the very intense degree of micritization. Both oval-shaped, elongated and isometric fragments can be found, the maximum size is no more than 1.8 mm. The rare echinoid fragments are small-sized and well-rounded. The coarse fraction includes shells and fragments of gastropods and brachiopods.

The intraclasts are well rounded micritic particles with micritic detritus and pellets.

The foraminifera association includes small-sized forms with a very poor preservation due to micritization. The following foraminifers can be found: various taxa of the Miliolidae family (mostly Quinqueloculina), Textulariidae family, Arenobulimina, Verneuilina, Mayncina, Cuneolina(?) and less frequently Pseudocyclammina(?) and orbitolinids.

This sediment was formed close to the internal part of the internal carbonate platform, in quiet, shallow water with normal salinity conditions. This facies was also found in all the three studied sections (Table III, 3).

**Biopelmicrite and biopelsparite with variable sized, micritized bioclasts, small foraminifera, rare oncolits and Bacinella**

The sediments of this facies were deposited in a shallow-water, infralittoral environment, probably in a lagoon setting. The sedimentary environment was very quiet, with normal sea-water salinity conditions and high algal productivity. This facies can be compared to the facies type F9 (Biosparites-biomicrites a Miliolides et petits rudistes) of A. Arnaud-Vanneau and Arnaud (1987, 1994).

Macroscopic characteristics. This massive limestone has a cream-like colour on both weathered and fresh surfaces.

Microscopic characteristics. Biopelmicrite and biopelsparite with variable-sized, micritized detritus, foraminifers, rare intraclasts and oncolits, Bacinella. The texture is packstone-grainstone.

The matrix makes up about 40% of the rock with a composition of micrite and/or sparite. The following components can be described:

a) Pellets (20-25%). These micritic particles have an oval-shape, without any observable internal structure;

b) Biodetritus (28-30%). About 80% of this component is partially or completely micritized and it is made up of variable sized fragments of pachyodonts, gastropods, undeterminable bivalves, brachiopods, strongly micritized dasyclades. The degree of rounding cannot be determined because of the strong micritization. The coarse bioclast fragments (up to 2.4 mm) are profoundly affected by micritization, perforation by endolithic alga and unicellular bacteria;

c) Intraclasts. These particles are made up of micrite with very fine grained biodetritus and foraminifers (Miliolidae);

d) Oncholits. The nucleus is made up of micritized organogenic fragments and the core is microgranular with very fine layering;

e) Bacinella. It forms a relatively large part of the rock occurring typically in a network structure;

f) Foraminifera. These components are strongly micritized and predominantly made up of the taxa of Miliolidae. Other forms can also be observed, such as Sabaudia, melathrokerion, Cuneolina(?), Neotrocholina, Textulariidae and orbitolinoids;

This facies was also found in all the three studied sections (Table III, 4).

**Pelmicrite with pachyodonts and Bacinella**

Macroscopic characteristics. This limestone has a light-blue to white colour on both weathered and fresh surfaces and a subdued nodular character. The macrofauna is composed of pachyodonts, chetetides, corals and brachiopods.

Microscopic characteristics. Pelmicrite with small-sized biodetritus, pachyodonts and Bacinella. The texture is wackestone-packstone.

The partially or completely micritized, fine biodetrital component is made up of unrounded fragments of pachyodonts with traces of the original structure obscured by micritization, perforation by endolithic algae and encrustation by Bacinella. The foraminifera association is poor, represented mostly by the rare forms of Quinqueloculina.

This facies, just like the previous one, can be included in facies type F9 (Biosparites-biomicrites a Miliolides et petits rudistes) of the Arnaud-Vanneau, Arnaud's (1987, 1994) classification. Sediments characterized by this facies were recognized in all the studied sections (Table IV, 1).
Microfacies types of the internal part of the internal platform. Medio- and supralittoral environments

**Biomicrite to biosparite with fine, micritized biodetritus, pellets, oncolits and Miliolidae**

This facies corresponds to that of F10 (Biopelmsparites-biomicrites a oncolites, Micrites a algal-mats) of the A. Arnaud- Vanneau and H. Arnaud's (1987, 1994) classification.

Macroscopic characteristics. This limestone has a light-blue to white colour and a massive texture.

Microscopic characteristics. Biomicrite with micritized detritus, oncolits and foraminifera. The texture is wackestone.

The matrix is composed of micrite, with pellets and small-sized, micritized biodetritus. The macrofauna is extremely poor, represented by rare fragments of bivalvia and gastropods. The very same fragments provide the nucleus for the oncolites. The core of the oncolites is microgranulated, mostly without a laminated structure.

Foraminifers are almost absent, except some forms of Miliolidae. The presence of *Bacinella irregularis* seems to be more characteristic.

The sediments of this facies were deposited in a shallow-water, protected and even closed area. This interpretation is based on the fairly poor organogenic association, the pronounced activity of unicellular algae and bacteria, resulting in intense micritization and oncolite formation. This particular facies has been observed only in the drillhole section “Preobrazhenski manastir” (Tabl. IV, 2).

**Interpretation of the microfacies evolution in the studied sections**

**Drillhole section “Preobrazhenski manastir”**

Based on the above described microfacies analysis, the sediments encountered in this drillhole section were dominantly deposited in inner platform environments (F7 through F10 facies groups). Facies types, characteristic for the external platform (i.e. slope and rim of the platform), seem to be of secondary significance (F5 and F6 facies groups).

In the drillhole section an interval of carbonate rocks was observed (between 49.6-56.7m) with mixed features. Unfortunately these distinctive features did not allow a direct correlation with the Arnaud-Vanneau, Arnaud's (1987, 1994) scheme. Macroscopic characteristics of these carbonate rocks include a dark gray colour on weathered and a medium gray colour on fresh surfaces. These muddy limestones have a massive texture and a biodetritic to intraclastic structure. Fragments and entire shells of pachyodonts can be frequently found.

Based on the microscopic features this facies can be best understood in terms of pelbiomicrite to pelbiosparite with polygenetic, variable sized biodetritus. The texture is that of a wackestone and packstone (Tabl. IV, 3).

The matrix of the rock is a micrite and/or microsparite having a significant amount (10 to 30%) of small-sized, oval-shaped pellets and fine shell debris (ostracods, bivalves). Occasionally planktonic foraminifers can be found with preserved internal organogenic layers and spicules of siliceous spongae, all of these suggesting a deep-water sedimentary environment. Orbitolinids are represented by both high- and low-conical forms. As Arnaud (1994) pointed out, large, flat foraminifers (such as orbitolinids) are characteristic for the circalittoral zone and they were never observed in the internal platform area, except in the stages of transgression.

The coarse bioclastic fraction also has a mixed composition. It is represented by various gastropod fragments with rich, well-preserved external ornamentation, fragments of pachiodonts, other thick-walled bivalves, coarse fragments of echinoids, whole shells of brachiopods and corals encrusted by *Lithocodium*.

The terrigenous clastic content (quartz) of the rock ranges from 2 to 7.5%. The average size of both poorly and well-rounded quartz grains is about 0.03 mm, with a maximum of 0.06 mm. They are evenly dispersed in the matrix or form intraclasts.

The foraminifera association is diverse (mostly circa- and infralittoral forms, as it was mentioned above), including the following families: Textulariidae, forms of Miliolidae, *Gaudryina, Marsonella*, high-conical and flat, low-conical orbitolinids, rare planktonic foraminifers and *Neotrocholina*.

The sediments of this facies can be described as belonging to a transgressive facies in the sense of Arnaud-Vanneau (1980). The most probably place of this particular transgressive facies (FT) in the theoretical profile of the carbonate platform cannot be determined, since the corresponding sediments seemingly do not follow any spatial pattern. Towards the internal platform, however, a certain gradual transition can be observed between the transgressive facies and the earlier described external platform (slope) facies (F3 in the Arnaud-scheme). The following transition can be observed:

Transgressive facies (FT) biopelmicrite to biopelmsparite with poligenetic, unsorted biodetritus, *Everticyclammina* facies (F3) biomi-
crite with corals, unsorted biodetritus, *Lithocodium* and encrusting sponges (F7-8).

Facies types of the external platform (external slope and rim of the carbonate platform) indicating a decrease of water depth and an increase of energy were identified in the lowermost part (57.18-61.5 m) of the drillhole section, immediately below the above described transgressive facies. The upper part (1-2 m thick) of this interval is a biopelmicrite to biopelsparite with pachyodonts, small foraminifers, biodetritus, *Salpingoporella*, classified as F8-9 in the Arnaud-Vanneau, Arnaud's (1987, 1994) scheme. The bioclastic component in these facies types is characterized by strongly mixed associations including mainly allochthonous elements. At these levels diagenetic anomalies can be observed, in the form of small, rhomboidal monocrystals of dolomite and in the partial, secondary dolomitization of the matrix. The transition from the internal to the external area of the carbonate platform is gradual, with the following consecutive facies types:

- biomicrite with corals, unsorted biodetritus, *Lithocodium*, encrusting sponges (F7-8) → biomicrite to biomicroparite with pachyodonts, dasycladacea, chetetides, corals, *Bacinella*, pellets and large foraminifers (F8) → biopelmicrite and biopelsparite with variable sized, micritized biodetritus, pellets, small foraminifers, rare oncholits and *Bacinella* (F9) → biomicrite to biosparite with micritized detritus, oncholits and Miliolidae (F10).

It is suggested here that the sediments of the lowermost part of the drillhole section were deposited in a transgressive period. During this high relative sea-level the sediments were deposited at the external part of the carbonate platform (external slope) in a microfacies characterized by biopelmicrite and biopelsparite with poligenetic, unsorted biodetritus and *Everticyclammina* (F3). Following a relative sea-level fall, during an extended period of time, a thick sedimentary succession was formed with sediments of the internal platform. The mostly lagoonal environment remained during this time remained in a close connection with open sea.

The microfacies of the uppermost part of the section seems to herald another transgressive period. Thus the evolution of microfacies outlines a more or less symmetric facies cycle in the drillhole section “Preobrazhenski manastir”.

**Outcrop section, near Emen village**

The curve defined by the evolution of microfacies in the outcrop section of Emen has a less diverse, monotonous character. However, this section can be subdivided into two intervals separated by a sudden change in the sedimentary environment.

The first interval corresponds to the lower part of the section (from 3 to 5.8 m) where in a typical backreef facies a significant input of terrigenous material (up to 6%) can be observed in the form of unrounded quartz grains (maximum size: 0.006 mm). The limestone from the bottom of this interval has a massive appearance with a cream-like colour on weathered surfaces and with thin lenses of yellowish limy clay. Further up in the section the limestone has a thin-bedded character with a bluish-cream colour on weathered surfaces and with a biodetritic texture.

The second interval is dominated by sediments composed of well-rounded biodetritus (Tab. 4, 4). In the upper level of the section, between 41-42 m, a grayish-yellow, somewhat sandy layer with sharp boundaries is intercalated within the pachyodont-bearing, grayish coloured limestones. This sandy biodetritic limestone has a microfacies of biomicrite to biomicroparite and biosparite with coarse, well-rounded biodetritus, intraclasts and pellets (facies F5 of the Arnaud-Vanneau, Arnaud's scheme). The bioclastic component is represented by strongly mixed association including organogenic elements typical for different areas of the carbonate platform. The microfacies of this 1 m thick, somewhat anomalous layer can be hardly related to the embedding limestones, mostly because of the lack of exposures immediately below and above of it.

The different microfacies patterns of the above described sedimentary intervals are due to a sudden change of relative sea-level.

The dominant part of the section is composed of limestones with pachyodonts. The specific feature of the microfacies types in this unit indicate a sedimentary environment in a relatively calm, shallow-water (infralittoral zone) setting, most probably in the inner platform area. The most characteristic facies type suggests a proximity of sedimentation to the rim of the platform, comparatively well protected from wave action, in the backreef and external parts of the internal carbonate platform.

The gradual transition from a relatively internal to a more external part of the platform is indicated in the following, consecutive facies types: biopelmicrite to biopelsparite with pachyodonts, small foraminifers, biodetritus and *Salpingoporella* (F8-9) → biomicrite to biomicroparite with pachyodonts, dasycladacea, chetetides, corals, *Bacinella*, pellets and large foraminifers (F8) → biomicrite with corals, unsorted biodetritus, *Lithocodium*, encrusting sponges (F7-8).
Fig. 4a. A, Outcrop section of the Emen Formation at the section "Al. Stamboliyski" dam, lower part. B, Textural types of carbonate rocks after Dunham (1957) and quantitative distribution of allochems. C, Curve illustrating the vertical evolution of microfacies, for legend see Fig. 3C.
Fig. 4a. A, Outcrop section of the Emen Formation at the section "Al. Stamboliyski" dam, lower part. B, Textural types of carbonate rocks after Dunham (1957) and quantitative distribution of allochems. C, Curve illustrating the vertical evolution of microfacies, for legend see Fig. 3C
Conclusions

The microfacies analysis of sediments of the Emen Formation in the three studied sections revealed an almost complete spectrum of facies types of a carbonate platform. The most dominant of these types, however, were those of the internal platform area. These results confirm the earlier interpretation of Хрисев (1969) and the palaeogeographic reconstruction of Хрисев, Бакалова (1974) based on the distribution of algal populations. The sedimentation of the Emen Formation occurred mainly in shallow-water, lagoonal environment. It should be noted, however, that during the evolution of the platform some departures took place from this sedimentation style. The resulting sediments have a specific facies signature. These marker levels, on one hand, can be used for the correlation between the different sections of the Emen Formation in different areas and, on the other hand, they can also be used for the reconstruction of the Emen carbonate platform through time. For the latter approach, however, additional data would be required for age determination of these specific horizons.

In this study an attempt has been made to compare the observed microfacies types of the Emen Formation with a theoretical Lower Cretaceous facies profile proposed by Arnaud-Vanneau, Arnaud (1987; 1994). Striking similarities were observed which allowed the classification of the facies types within the same scheme. Moreover, based on the vertical stacking of distinct facies types, certain changes in sedimentation style were outlined in the studied sections, driven by relative sea-level changes.

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