Acta Geologica Hungarica, Vol. 49/2, pp. 125–163
DOI: 10.1556/AGeol.49.2006.2.3

Displaced Jurassic foreslope and basin deposits of Dinaridic origin in Northeast Hungary

János Haas
Geological Research Group of the Hungarian Academy of Sciences, Eötvös Loránd University, Budapest

Ágnes Görög
Paleontological Department, Eötvös Loránd University, Budapest

Sándor Kovács
Geological Research Group of the Hungarian Academy of Sciences, Eötvös Loránd University, Budapest

Péter Ozsvárt
Research Group for Paleontology, Hungarian Academy of Sciences–Hungarian National History Museum, Budapest

Ilona Matyók
Budapest

Pál Pelikán
Hungarian Geological Institute, Budapest

The basement of the Pannonian Basin is made up of tectonostratigraphic terranes of varying origin. They gradually amalgamated to form the large Alcapa and Tisza–Dacia composite terranes that were juxtaposed during the Tertiary. In North Hungary, in the basement of the Tertiary volcanic complex of the Mátra Mts and in the western part of the Bükk Mts, remnants of a Jurassic accretionary wedge were encountered. Ore exploration boreholes encountered several hundred-meter thick carbonate and siliceous shale-radiolarite successions in the basement of the Mátra Mts (Darnó Complex). Based on detailed studies of Core Recsk-109, the carbonate succession consists predominantly of grainstone with packstone–wackestone intercalations. Peloidal bioclastic grainstone is the most common texture type but sand-sized intraclasts and oncoid and ooid grains also occur locally. The most spectacular feature is the large amount of coarse to medium sand-sized fragments of calcified cyanobacteria ("Porostromata"). Platform-derived foraminifera and fragments of crinoids are also common. Gravity flows transported the carbonate detritus to the site of deposition at the lower foreslope and proximal toe-of-slope. Based on foraminifera the succession is Aalenian? or Early Bajocian in age.

In the southern part of the Bükk Mts fine-grained, graded oolitic, peloidal grainstone with shale and radiolarite interlayers occur in surface exposures and cores (Bükkzsérc Limestone Formation). These deposits were formed via turbidity currents in a basin relatively far from the carbonate producing platforms. Based on foraminifera the age of the formation is Early Bajocian–Bathonian. Radiolarian faunas suggesting Late Bajocian–Early Bathonian and Early Bathonian–Early Callovian age respectively, were found in a silicified carbonate and radiolarite succession that occurs below the Bükkzsérc Limestone with a tectonic contact.

Addresses: J. Haas, S. Kovács, Á. Görög: H-1117 Budapest, Pázmány P. sétány 1/c, Hungary,
e-mail: haas@ludens.elte.hu
P. Ozsvárt: H-1431 Budapest, P.O. Box 137, Hungary
I. Matyók: H-1039 Budapest, Lékai tér 1, Hungary
P. Pelikán: H-1143 Budapest, Stefánia út 14, Hungary
Received: June 16, 2006, accepted: July 2, 2006

In the wider region Middle to Late Jurassic carbonate platforms and reef facies are known only in the Dinarides, in the area of the Adriatic (Dinaridic) Carbonate Platform. Coeval platform-derived redeposited carbonates and intercalated pelagic basin deposits were reported from the slopes of the Adriatic platform and the periplatform basins of the Slovenian Trough and the Bosnian Flysch Zone. These data confirm the previously suggested paleogeographic connections between the Dinaridic units and the Darnó and Bükk units during the Jurassic.

Key words: Jurassic, redeposited carbonates, foreslope, basin, foraminifera, radiolarians, paleogeography

Introduction

In the last decades the results of geologic mapping and tectonic studies in the western part of the Bükk Mountains (Balla et al. 1980; Csontos 1988) and the recognition of Jurassic formations (Bérczi-Makk and Pelikán 1984; Csontos et al. 1991a, b) fundamentally altered the previous concepts on the structure and geodynamical setting of the area. The new stratigraphic and tectonic data led to the recognition of nappe structure of the mountains (Balla et al. 1983; Csontos 1988). According to this concept a parautochthonous unit made up of formations formed on continental crust is overthrust by rock complexes derived from the oceanic basement and the continental slope.

In the late 1960s and 70s, ore exploration boreholes penetrated the Mesozoic volcanic and sedimentary complexes in the basement of the Tertiary formations in the eastern Mátra Mts (Földessyné 1975). Detailed investigations revealed Triassic and Jurassic oceanic basalt and sedimentary rocks of basin and slope facies in these cores, similar to those that occur in the western Bükk Mts (Dosztály and Józsa 1992). According to the interpretation of Csontos (1999) and Haas and Kovács (2001) these magmatic and sedimentary rock bodies are parts of a Late Jurassic accretionary complex, which was overthrust onto the Bükk Parautochthonous Unit. The parautochthonous and the overthrust complexes were affected by multiple deformations in the Cretaceous prior to the large-scale displacement of the entire terrane in the Tertiary.

Limestone consisting of redeposited carbonate grains (Bükkzsérc Limestone Formation) occurs both in the Mónosbél Unit of the Mónosbél–Szarvaskő Nappe in the Bükk Mts and in the magmatic-sedimentary complex in the Darnó area. These rocks provide valuable information on their source and depositional areas and contain age-diagnostic fossils. The existence of Jurassic rocks in the Bükk Mts was first suggested by the recognition of Jurassic foraminifera in these limestone units (Bércziné Makk and Pelikán 1984). Based on studies of outcrops and cores in the Bükk Mts reports on the biostratigraphy of the Bükkzsérc Limestone were subsequently published (Bérczi-Makk et al. 1989; Bércziné Makk 1999; Pelikán and Dosztály 2000). However, no report on the sedimentological characteristics and biostratigraphy of similar carbonate rocks which occur in the Darnó area has been published so far, except for a short report by Dimitrijević et al. (2003).

In this paper results of new investigations of Jurassic carbonate sequences are presented, including the study of a core section (Recsk, Rm-109) in the Darnó area (Mátra Mts) and a quarry section complemented with core sections in the type locality of the Bükkzsérc Limestone Formation in the Bükk Mts. These studies permitted correlating the two successions and to compare their sedimentological and biofacies characteristics. The new age determinations confirmed the previously assumed differences between the Jurassic successions of the parautochthonous unit and those of the nappes. These studies also allowed the determination of the original setting of the displaced blocks, which is one of the key questions of the geodynamic evolution of the Dinaridic–Pannonian–West Carpathian region. Based on similarities in the litho- and biofacies characteristics of Upper Paleozoic to Triassic sequences, a Dinaridic origin of the Bükk was already suggested by Schréter (1959) and by Balogh (1964). This concept was confirmed by the result of detailed comparative studies (Protić et al. 2000; Pamić et al. 2002; Filipović et al. 2003; Dimitrijević et al. 2003). The paleogeographic relationship of the Jurassic complexes of the Darnó–Bükk area and that of the ophiolite mélange of the Internal Dinarides and the Bosnian Flysch Zone was proposed by Pamić (1997 2003). Our studies of Jurassic re-deposited carbonates in the Darnó area and in the Bükk Mts yielded new evidence to support this concept.

G*eologic setting*

The study area is located in NE Hungary; it includes the eastern Mátra Mts and the western Bükk Mts (Fig. 1). The Bükk Mts are made up of the Bükk Parautochthonous Unit containing Upper Paleozoic to Jurassic formations. The Jurassic succession begins with Callovian–Oxfordian radiolarite (Bányahegy Radiolarite Formation). It is overlain by a dark-gray shale sequence (Lökvölgy Formation), which is made up of turbidites with sandstone base grading upward into silty claystone. There is no direct evidence for its age. The parautochthonous unit is overthrust by nappes containing Jurassic deep-sea shale, sandstone and radiolarite, redeposited calcarenite of toe-of-slope facies, lower-slope debrites (olistostromes) (Mónosbél Unit) and gabbro and pillow basalt (Szarvaskő Unit) (Balla 1983; Dosztály et al. 1998; Dimitrijević et al. 2003). The Mátra Mts are made up predominantly of Tertiary volcanic rocks and sedimentary sequences. Only relatively small outcrops of pre-Tertiary rocks occur at the northeastern margin of the mountains (Darnó Hill). However, a great number of mineral exploration boreholes reached the pre-Tertiary basement in the eastern part of the Mátra Mts, in the Darnó area. Upper Paleozoic and Triassic rocks that most probably belong to the Bükk Parautochthonous Unit occur in the basement of the Darnó Complex, which is made up of Jurassic deep-sea shale, claystone, radiolarite, redeposited calcarenite, debrites, purple to red amygdaloidal basalt with limestone inclusions (probably Triassic in age) and greenish-gray pillow basalt (probably Jurassic in age) (Dosztály and Józsa 1992; Dosztály et al. 1998 2002).

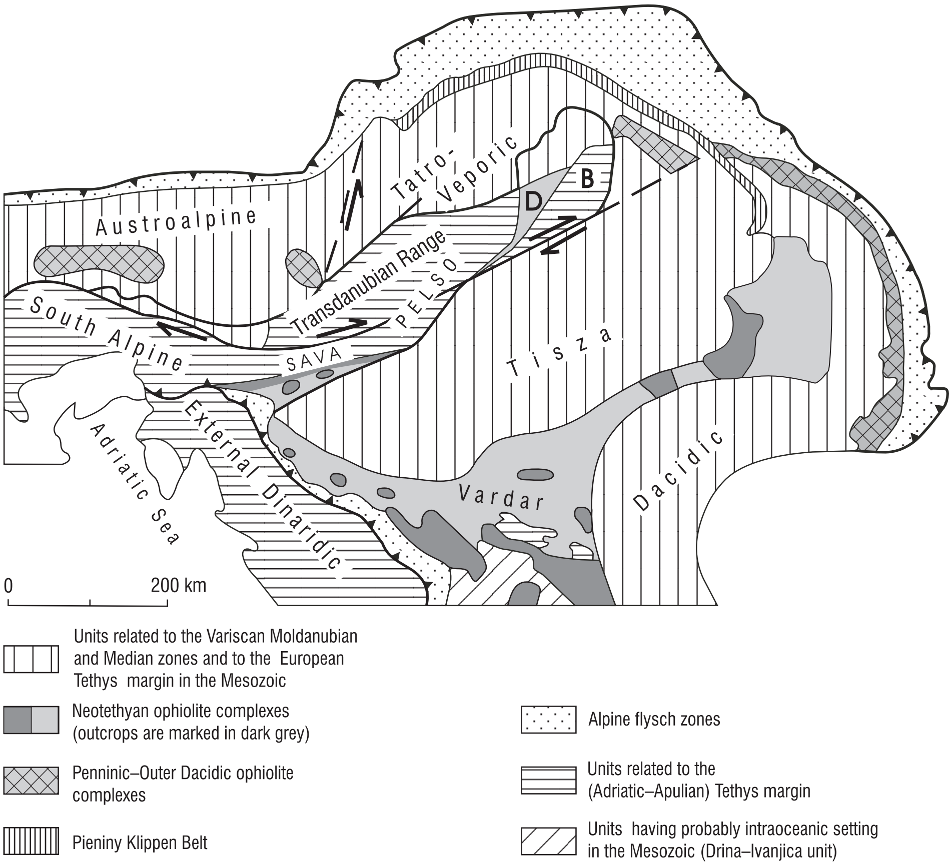


Fig. 1
Structural units of the pre-Tertiary basement of the Pannonian Basin and the surrounding mountain ranges and position of the study area. D – Darnó area, B – Bükk Mts

Results

Core Recsk Rm-109

Core Rm-109 was cut north of Mount Kékes, about 5 km SW of Parádfürdő, eastern Mátra Mts (Fig. 2), in 1975. The borehole penetrated Oligocene deep marine black shale. Below it gray and red silty marl with carbonate clasts was encountered between 893.6–942.0 m. Since no fossils have been found in this unit, its age is unknown, but most probably Tertiary.

The more than 250 m-thick (942.0–1200.0 m) penetrated Jurassic sequence is made up of two different lithofacies units (Fig. 3A). The lower unit (1076.5–

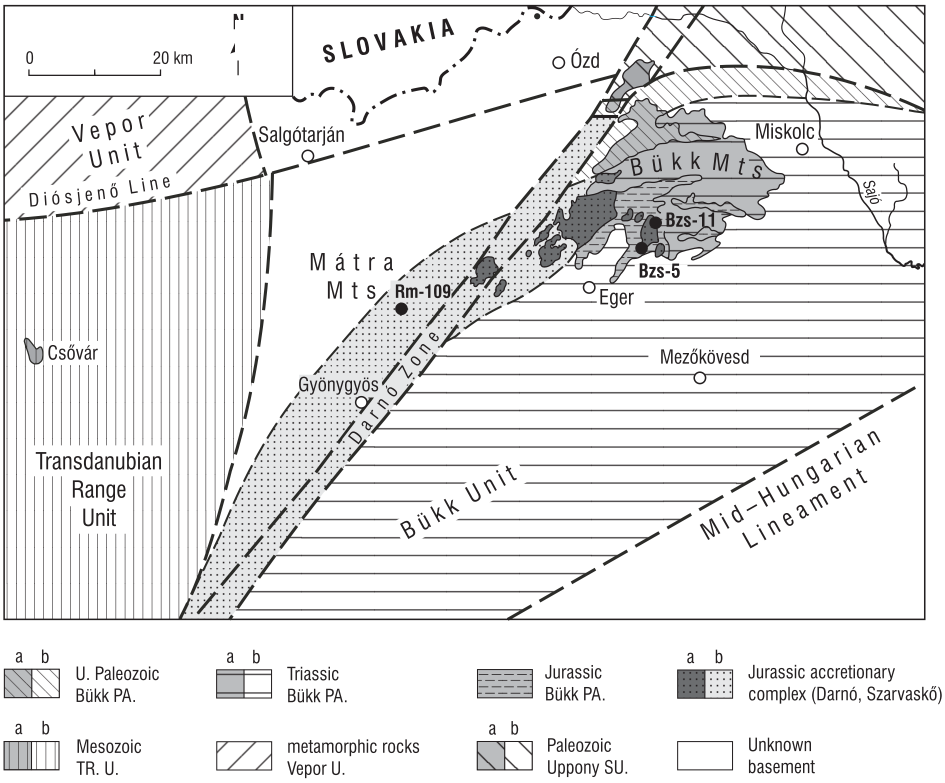
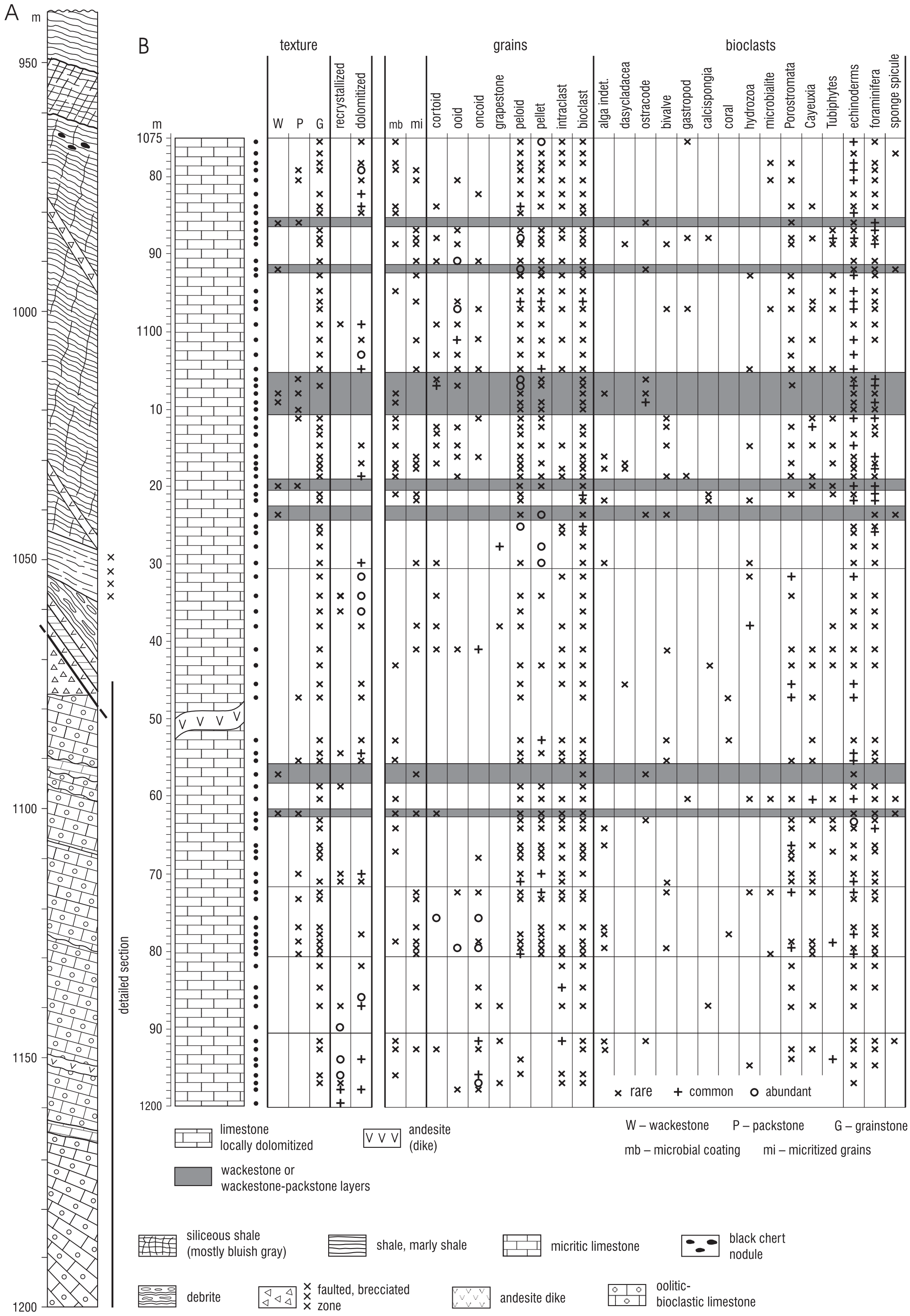


Fig. 2
Geologic map on the pre-Tertiary subcrop of the Mátra–Bükk region, showing locations of the studied sections. a) Outcrops, b) subsurface extension of the formations

1200.0 m) consists of gray to brownish gray limestone. It is rather uniform macroscopically; however, various microfacies types could be distinguished. The microscopic studies revealed that recrystallization and partial dolomitization are common in some parts of the carbonate succession (Figs 3B and 4), which can be attributed to the effect of hydrothermal fluids. In the highly dolomitized intervals the original sedimentary texture could not be determined. The upper lithofacies unit (942.0–1076.5 m) is made up of dark bluish gray, locally red siliceous shale with a light gray chert intercalation between 949.1–955.4 m. The contact of the carbonate unit and the upper shale unit is sharp, probably tectonic. Andesite dikes occur both in the limestone and the shale intervals.


A
m
950
1000
1050
1100
1150
1200
detailed section
B
texture
grains
bioclasts
W P G recrystallized dolomitized
mb mi cortoid ooid oncoid grapestone peloid pellet intraclast bioclast
alga indet. dasycladacea ostracode bivalve gastropod calcispongia coral hydrozoa microbialite Porostromata Cayeuxia Tubiphytes echinoderms foraminifera sponge spicule
m
1075
80
90
1100
10
20
30
40
50
60
70
80
90
1200
× rare + common o abundant
limestone locally dolomitized
andesite (dike)
wackestone or wackestone-packstone layers
W – wackestone P – packstone G – grainstone
mb – microbial coating mi – micritized grains
siliceous shale (mostly bluish gray)
shale, marly shale
micritic limestone
black chert nodule
debrite
faulted, brecciated zone
andesite dike
oolitic-bioclastic limestone

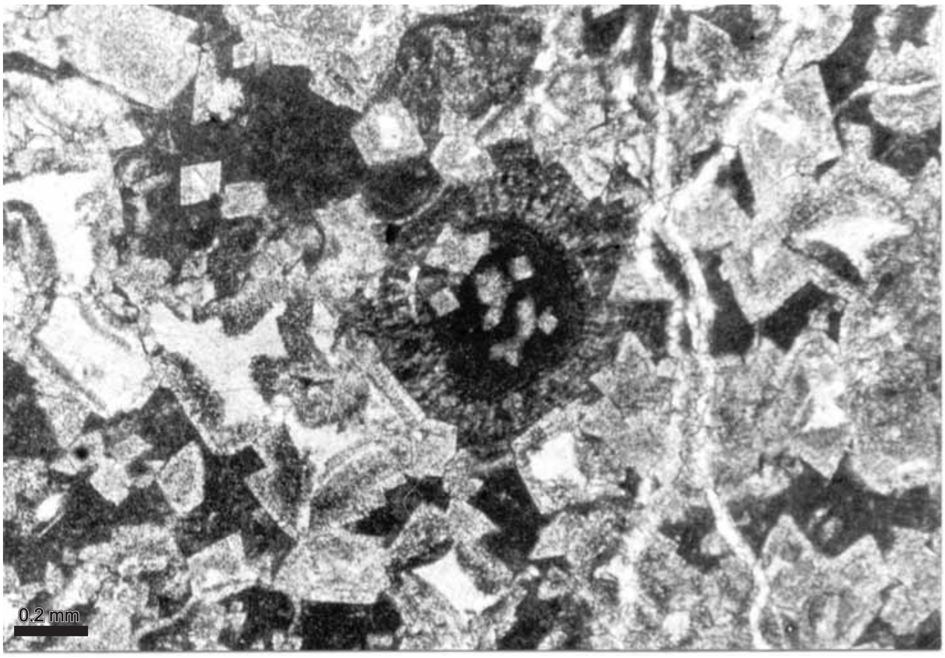


Fig. 4
Strongly dolomitized rock. Some elements of the original sedimentary texture can be still recognized

Microfacies types of the carbonate unit

The most important microfacies characteristics of the carbonate unit are presented in Fig. 3B, where grades of recrystallization and dolomitization are also displayed. The typical size range of the coated grains and peloids and the maximum size of the bioclasts are presented in Fig. 5. Based on microscope studies, the following microfacies types were defined.

Oolitic, oncoidal grainstone (Fig. 6a, b)

This type is characterized by the occurrence of coated grains: ooids, cortoids, oncoids, and aggregate grains (grapestone), usually in relatively large quantities. Along with the coated grains, peloids and various amounts of intraclasts and bioclasts also commonly occur. Micritic envelopes and microbial encrustation around the bioclasts are also common. Fragments of calcified cyanobacteria ("Porostromata" group) usually occur, locally in relatively large quantity. Detritus

← Fig. 3
A) Geologic column of the Mesozoic succession in borehole Recsk, Rm-109; B) Microfacies characteristics of the carbonate interval

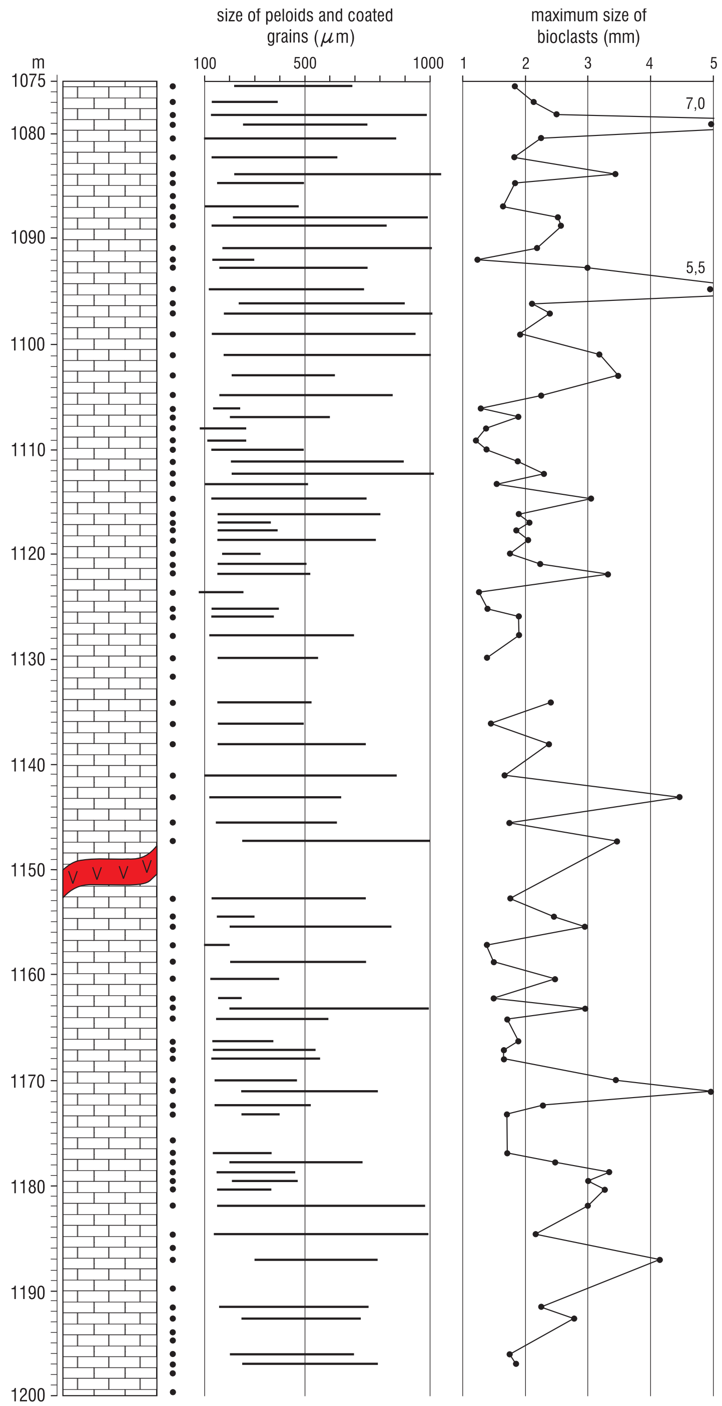
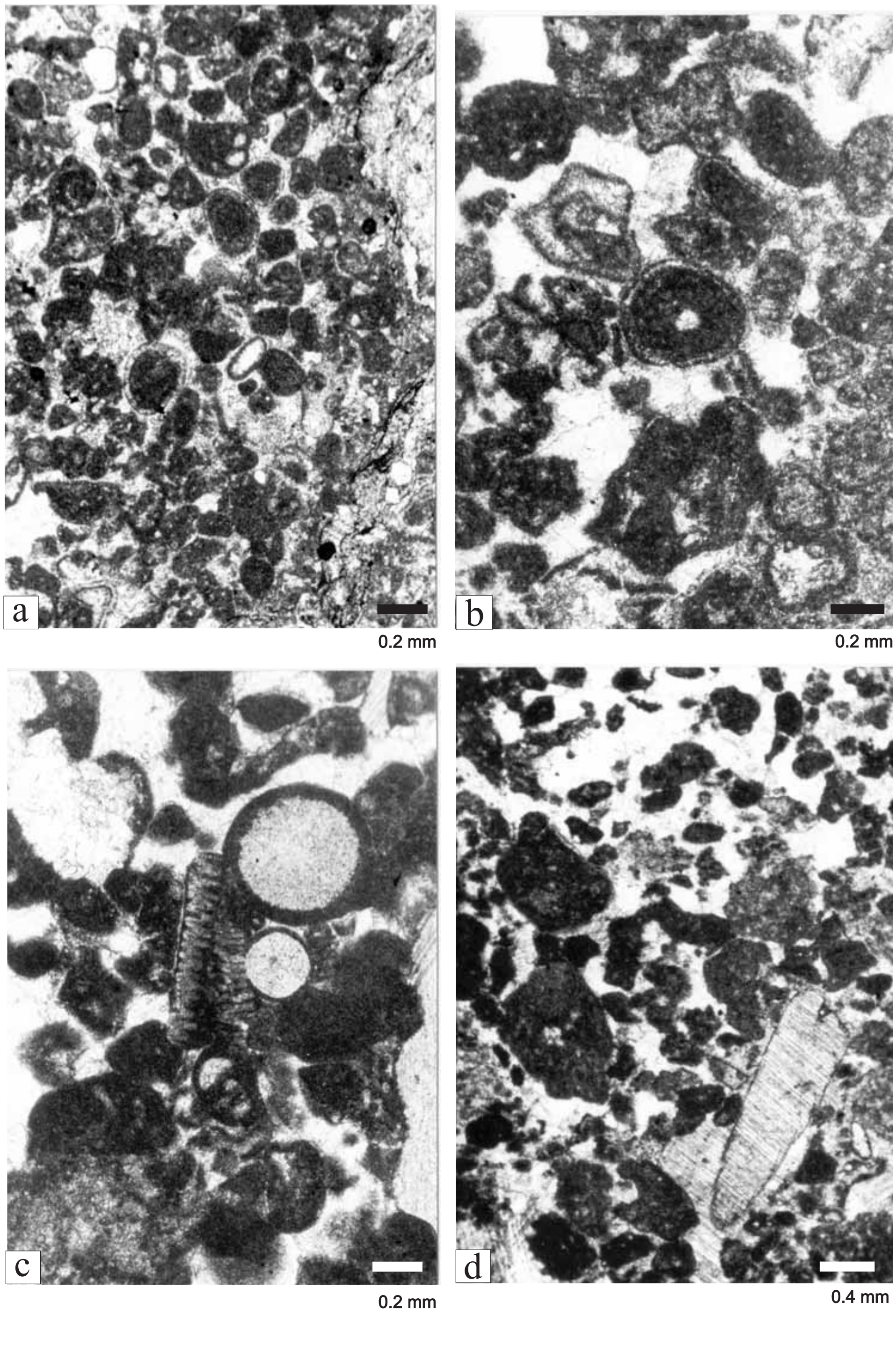


Fig. 5
Size of carbonate grains in the carbonate sequence of Core Rm-109

Fig. 6 →
Microfacies types in Core Rm-109. a) Oolitic, peloidal grainstone with aggregate grains, 1113.0 m; b) grainstone with Tubiphytes-type microbial remains and aggregate grains, 1192.5–1192.3 m; c) Peloidal, bioclastic grainstone. Note well-developed micrite envelope around bioclasts, 1095.0–1095.2 m; d) Peloidal, bioclastic grainstone with Tubiphytes-type microbial remains, 1163.2 m


a
0.2 mm
b
0.2 mm
c
0.2 mm
d
0.4 mm

of echinoderms, predominantly benthic crinoids and foraminifera, are also present.

Peloidal grainstone (Fig. 6c, d)

In the grainstone texture fine sand-sized peloids are predominant; coarser sand-sized intraclasts and bioclasts generally also occur. In contrast, coated grains are usually absent. Some of the peloids have a spherical or ovoid shape: these are identified as fecal pellets. The other small micritic grains are likely to be micritized bioclasts; however, a microbial origin of some of them cannot be excluded. Various types of calcified cyanobacteria ("Porostromata") and Tubiphytes-type microbial remains also commonly occur in this microfacies type. The amount of fragments of echinoderms (mostly crinoids) may change from rare to abundant, and foraminifera from rare to moderately common.

Intraclastic grainstone (Fig. 7a, b)

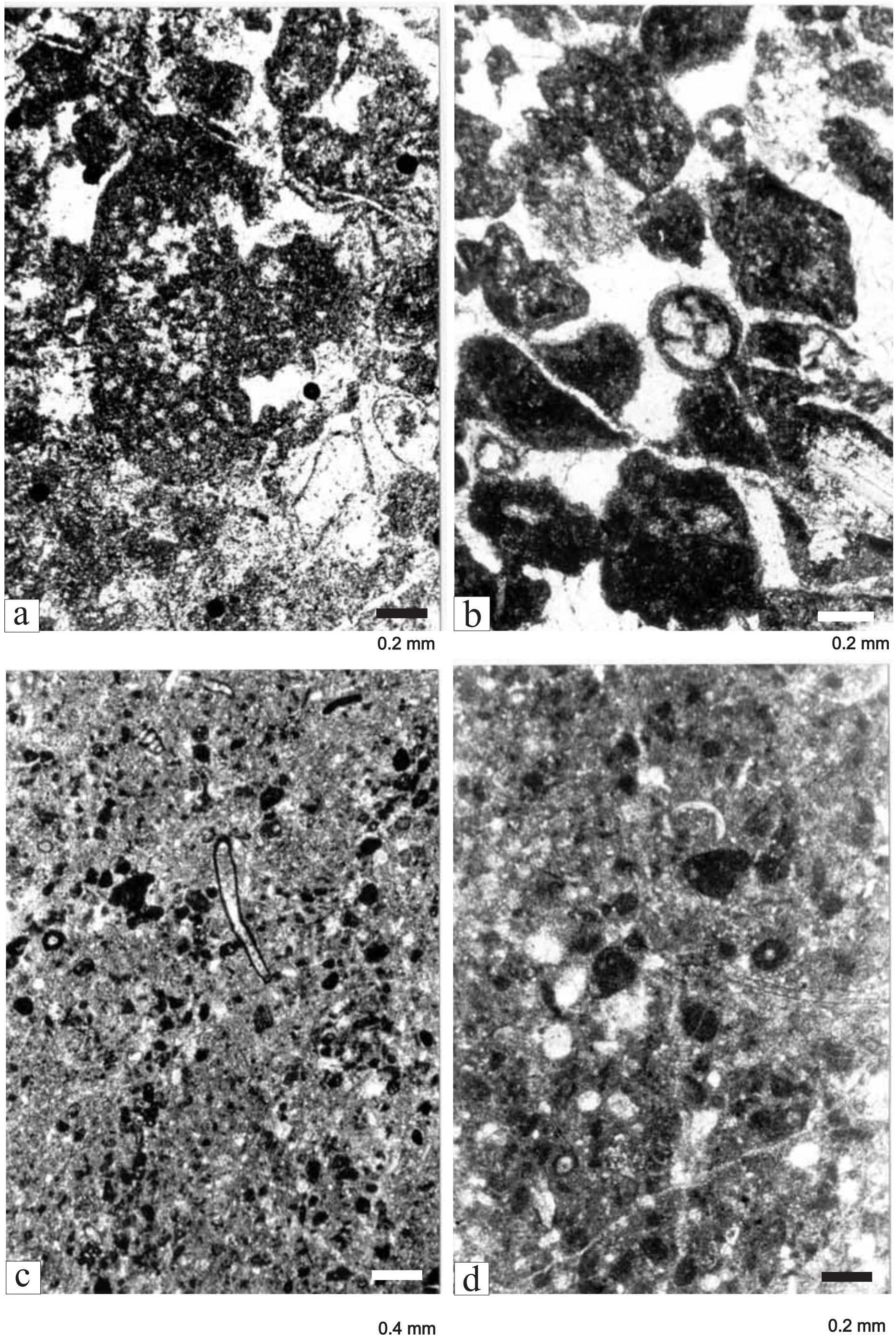
In this microfacies type the micritic particles are somewhat larger than in the peloidal grainstone. A predominant part of these particles are identified as intraclasts. Oncoids and aggregate grains also occur, albeit rarely. Fragments of "Porostromata", echinoderm (crinoid) detritus and foraminifera are generally present in small amounts only.

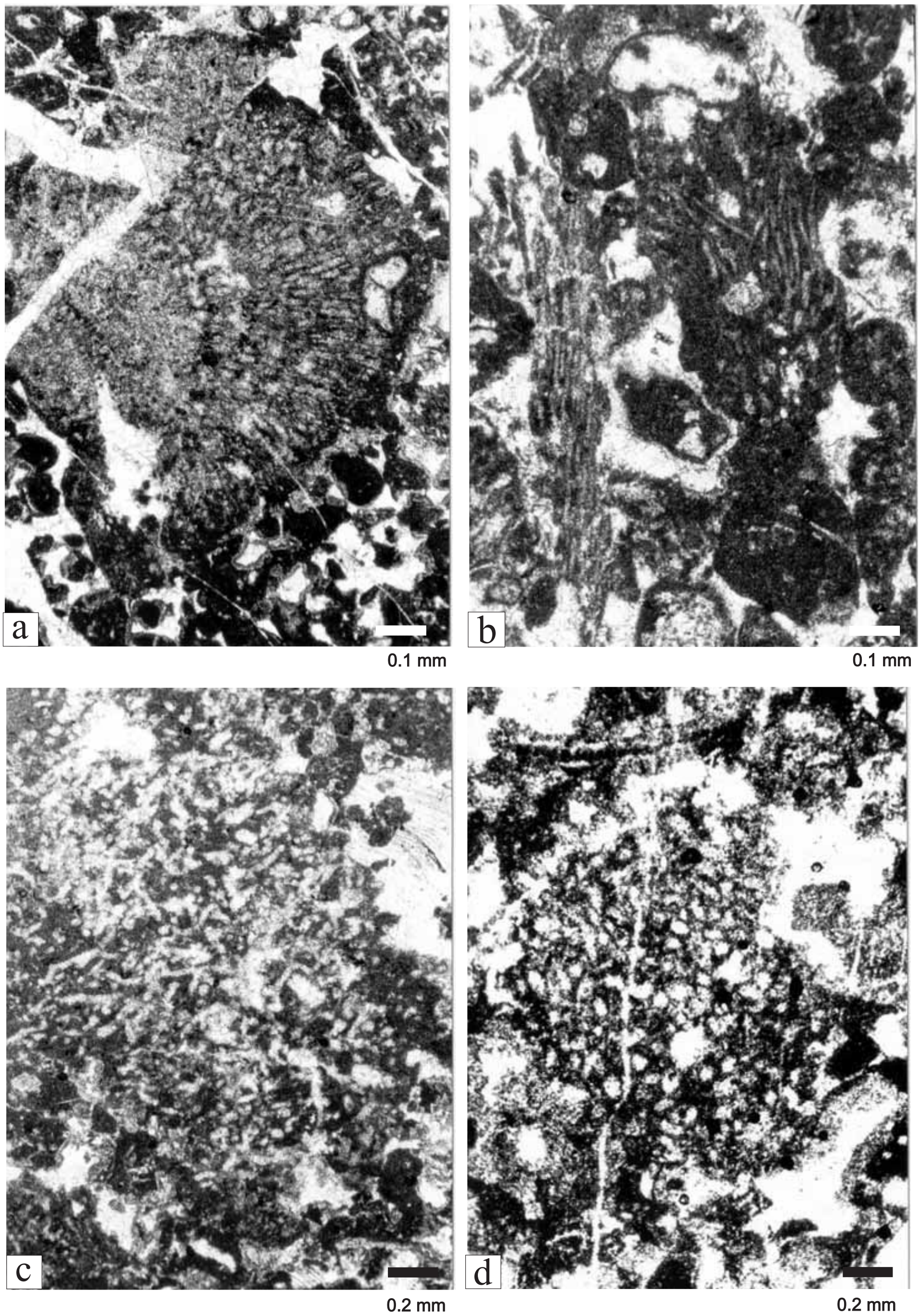
Peloidal wackestone (Fig. 7c, d)

This microfacies type is characterized by wackestone or locally packstone texture with varying amounts of peloids (incl. fecal pellets). It is poor in bioclasts; intraclasts are generally missing or rare. Echinoderm (crinoid) detritus and foraminifera are commonly present, in some horizons in relatively large quantities. Ostracodes and calcified spicules of silicisponges may also occur.

In summary, the more than 120 m-thick carbonate sequence shows rather uniform microfacies characteristics. Grainstone containing fine to medium-sized (0.1–1.0 mm) calcarenite is predominant. Further subdivision can be carried out on the basis of the most characteristic grain types (coated grains, peloids or intraclasts). Fragments of calcified cyanobacterial and other microbial fabric are ubiquitous (Figs 8, 9). In some samples these may occur in rock-forming quantity and their size may reach 5 to 7 mm (Fig. 5). Echinoderm (mostly crinoid fragments) and benthic foraminifera are also usually present in every microfacies type. Rare fragments of corals and calcareous sponges also occur locally. The wackestone or wackestone-packstone microfacies usually appears in decimeter to

Fig. 7 →
Microfacies types in Core Rm-109. a) Bioclastic, peloidal grainstone with fragments of "Porostromata", 1180.8 m; b) Intraclastic grainstone. Note micrite coating on the bioclasts, 1185.2–1185.3 m; c) Peloidal wackestone with *Aeolisaccus* sp., 1109.0 m; d) Peloidal wackestone with calcite molds of radiolarians, 1092.0 m


a
0.2 mm
b
0.2 mm
c
0.4 mm
d
0.2 mm


a
0.1 mm
b
0.1 mm
c
0.2 mm
d
0.2 mm

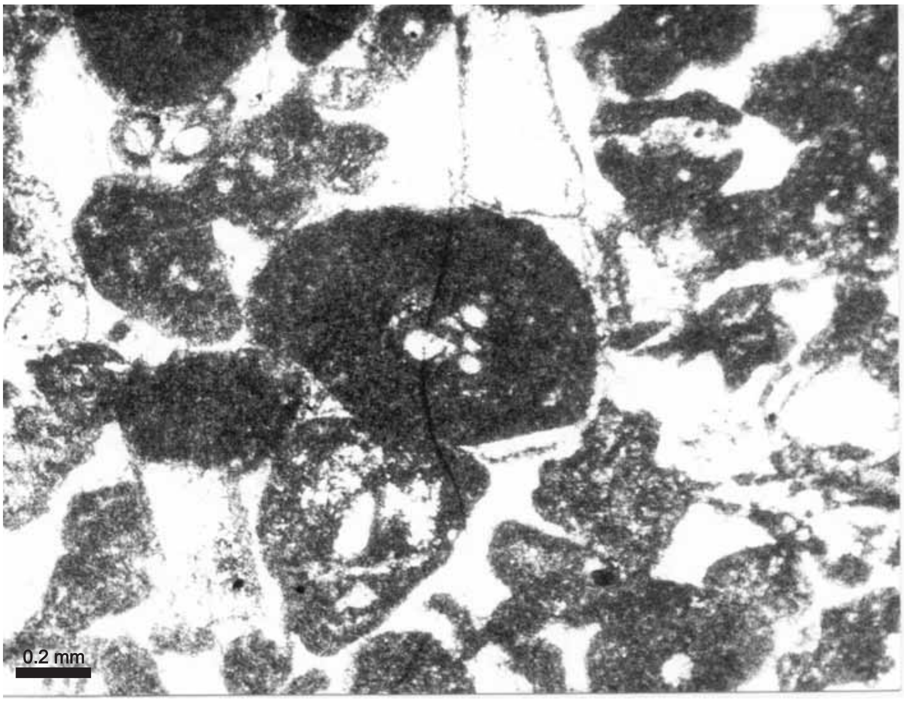


Fig. 9
Tubiphytes-type microbial remains. Core Rm-109, 1097.0–1097.2 m

meter-thick interlayers in the oolitic grainstone or peloidal grainstone facies; however, it was also found in a 6 m-thick interval (1105–1111 m).

Interpretation of the source area of the carbonate particles and depositional environment

The carbonate grains that make up the studied formations are unambiguously of shallow marine origin. Ooids form on wave-agitated margins of tropical carbonate platforms at a depth of less than 15 m (Flügel 1982). The oncoids are microbially-encrusted spherical grains that usually occur in less agitated parts of the platforms. Microbes play a crucial role in the binding of the aggregate grains, which typically occurs in the protected low-energy environments of the carbonate platforms.

←Fig. 8
Fragments of "Porostromata"-type calcified cyanobacteria. Core Rm-109 a) 1143.4 m; b) 1146.9 m; c) 1148.0 m; d) 1178.1 m

The composition of the biogenic particles provides further information on the source area of the bioclasts. The most typical elements of the grainstone facies are the calcified cyanobacterial remains ("Porostromata") and other microbial carbonate grains. The cyanobacteria are relatively large, aerobic phototrophic organisms. They live in oxygenated shallow-water environments in the water column or on the bottom (Riding 2000). Cyanobacterial calcification is crucial for preservation of the cyanobacterial remains. At present intense calcification takes place mainly under freshwater conditions although in a few cases it was also observed in modern subtidal environments. In contrast there are many examples of widespread cyanobacterial calcification also in marine environments in the past (Dragastan et al. 1996; Riding 2000). Since enhanced carbonate precipitation is an indispensable prerequisite of formation and preservation of microbial carbonates, the co-occurrence of ooids, oncoids and microbialites is not surprising.

Fragments of corals, calcareous sponges and hydrozoans that, along with microbial carbonate grains, also occur locally, indicate the presence of patch reefs at the platform margin, although their extent could have been rather limited.

The foraminifer fauna was investigated in the same thin sections of Core Recsk Rm-109 as was the microfacies. This is the first study on Jurassic foraminifera from this area. The fauna is relatively homogeneous throughout the section studied. The most characteristic taxa are presented in Fig. 10, whereas the habitats of some typical forms are displayed in Fig. 11. The agglutinated forms, mainly the *Textularia–Valvulina–Trocholina* (TVT) group is predominant. Besides these, specimens of *Siphovalvulina*, *Verneuilinoides* and *Glomospira* are also frequent, especially between 1106.5 and 1143.4 m. Mostly in the upper part of the section (1076–1106.5 m) there are also a few larger agglutinated forms of inner platform origin, e.g. *Redmondoides lugeoni* (Septfontaine), *Ammobaculites* and *Pseudocyclammina* sp., whereas *Gutnicella cayeuxi* (Lucas) indicates an outer platform habitat. In these parts of the core (1076.0–1143.4 m) microgranular forms, e.g. *Nautiloculina oolithica* (Mohler), *Aeolissacus* sp. and *Mesoendothyra croatica* Gušic, also occur. The inner platform may have been the habitat of the latter forms (Septfontaine 1978, 1981). The littoral *Trocholina conica* (Schlumberger) and both the low and high-spired variant of *T. palastiniensis* Henson, are most abundant also in the upper part of the succession (samples from 1190 m, 1143–1143.4 m, 1136.0 m, 1119.0 m, 1111.0–1112.3 m, 1107.0 m). The porcelanous forms are subordinate, except in two horizons. The lower horizon (1111.0 m) is characterized by *Labalina rawiensis* (Pazdrowa) that is typical for inner and middle platform environments whereas *Ophthalmidium concentricum* (Terquem et Berthelin) occurs in the upper horizon (1092.0 m), indicating an outer platform environment (Clerc 2005). Several specimens of other *Labalina* sp. and *Ophthalmidium* sp. could also be distinguished. The hyaline *Lagenidae* group is extremely rare in the studied samples.

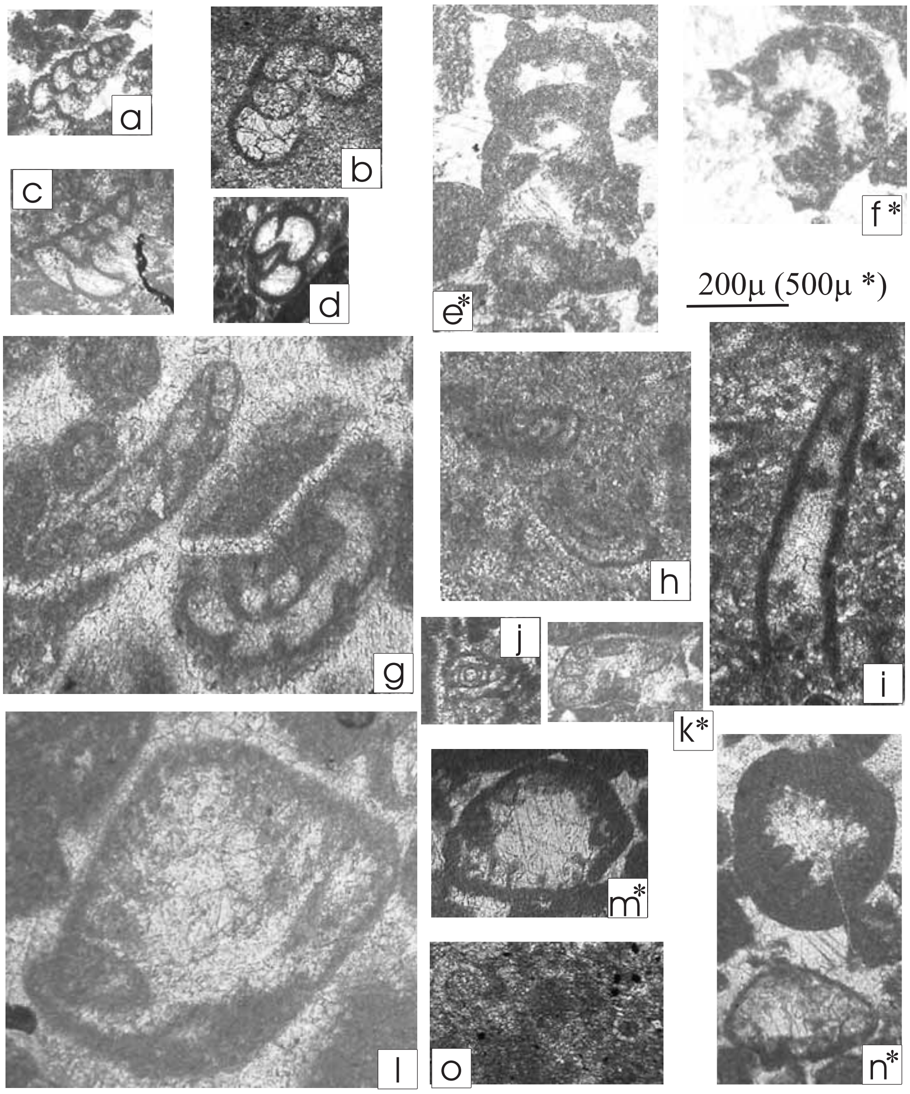
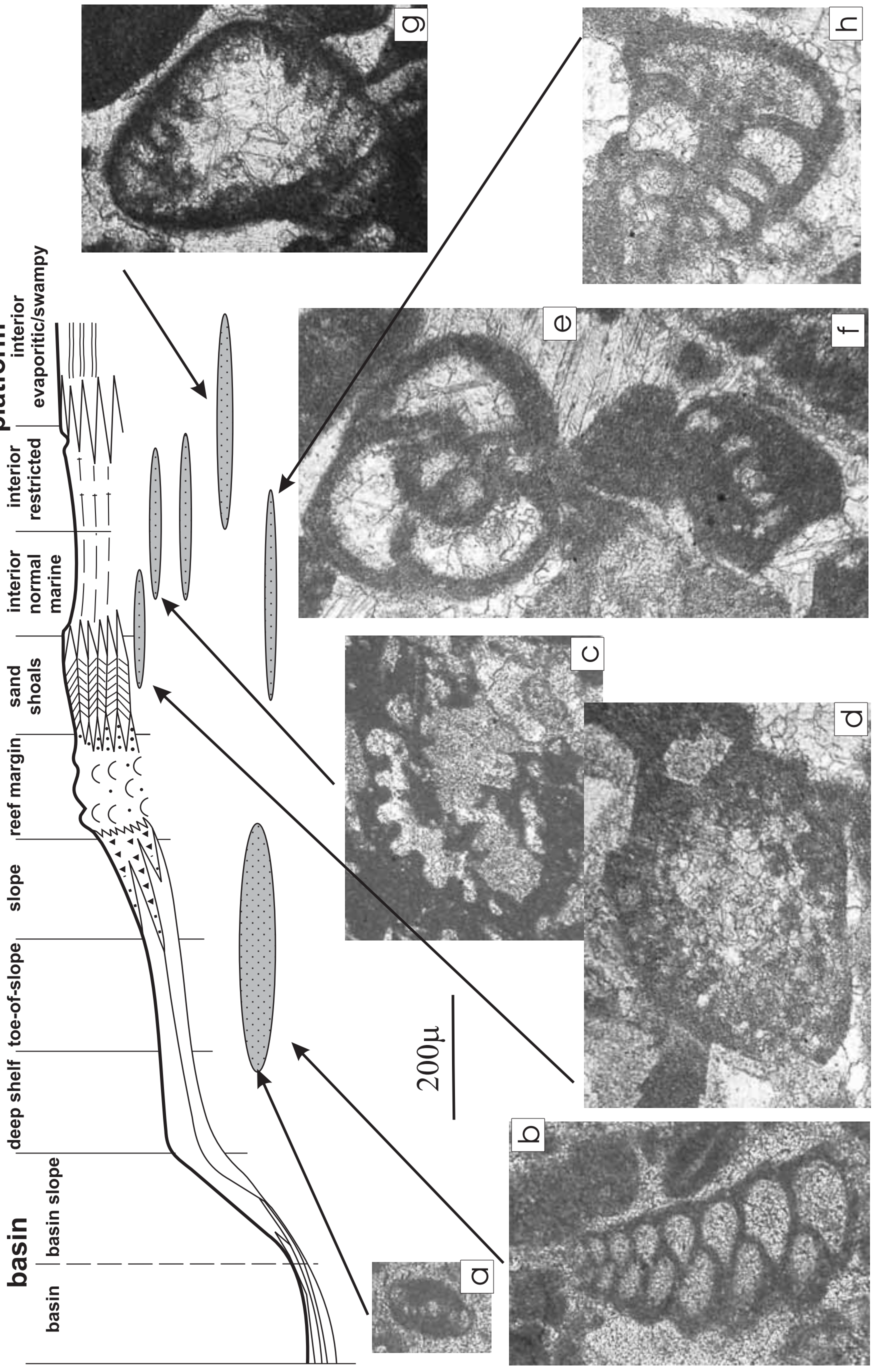


Fig 10
Characteristic microfossils in Core Rm-109. a) *Textularia* sp., 1122.3 m; b) *Trochammina* sp., 1124.3 m; c) *Verneuilinoides* sp., 1086 m; d) *Siphovalvulina*, 1110 m; e) *Ammobaculites* sp., 1076 m; f) *Pseudocyclammina* sp., 1141 m; g) *Patellovalvulina* sp. and *Mesoendothyra croatica* Gušić, 1116 m; h) *Ophthalmidium concentricum* (Terquem et Berthelin), 1092 m; i) *Aeolissacus* sp., 1108m; j) *Labalina rawiensis* (Pazdrowa), 1111 m; k) T*rocholina conica* (Schlumberger), 1193 m; l) *Trocholina palastiniensis* Henson, 1111 m; m) *Trocholina palastiniensis* Henson, 1193 m; n) *Trocholina palastiniensis* Henson (high form) and *T. conica* (Schlumberger), 1143 m; o) Cadosinas, 1106 m


platform
interior evaporitic/swampy
interior restricted
interior normal marine
sand shoals
reef margin
slope
toe-of-slope
deep shelf
basin
basin slope
basin
200μ
a
b
c
d
e
f
g
h

Fragments of benthic crinoids are also common and form characteristic components of the studied carbonate succession. In the Jurassic the slopes and slope terraces were typical habitats of the benthic crinoids (Jenkyns 1971; Galácz and Vörös 1972). In the present case the upper platform foreslope may have been the source area of the crinoid detritus.

The toe-of-slope environment may have been the site of deposition of carbonates encountered in Core Rm-109. A predominant part of the grains (coated grains, peloids, fragments of calcified cyanobacteria, foraminifera, crinoids, etc.) were derived from the neighboring carbonate platform and upper part of the platform foreslope. The grainstone texture indicates a high-energy depositional environment. Strong currents may have transported and redeposited the carbonate sand, while winnowing the fine fraction. It is probable that the coarser-grained intraclastic microfacies type is the most proximal whereas the oolitic and the peloidal facies are more distal deposits. The peloidal wackestone represents the most distal facies that was deposited in a relatively deep basin.

Biostratigraphy

The biostratigraphy of the limestone interval is based on the foraminifer fauna. Radiolarians were found in a single sample taken from silicified shale about 75 m above the top of the limestone succession. The tectonic contact of the limestone and the shale unit must also be taken into account for the chronostratigraphic evaluation of the carbonates. The stratigraphic ranges of some foraminifer species are presented in Fig. 12.

No foraminifera were found in the uppermost part of the studied section (1076–1059.0 m). In the upper part of the foraminifera-bearing interval the trocholinas, namely *Trocholina conica* (Schlumberger) and both the low and high-spired variants of *Trocholina palastiniensis* Henson are abundant. These species are frequently used as age-diagnostic forms. The trocholinas are common in the Middle and Upper Jurassic carbonates; their sections are often illustrated in the published literature. However, most of these sections are not suitable for specific determination due to oblique sections, strong abrasion and/or missing last whorl. The only axial section of the type specimen of *Trocholina conica* to be published so far was by Henson (1948) from the Middle Jurassic. Of *T. palastiniensis* Henson showed only strongly subaxial sections, but later Derin and Reiss (1965) presented a few acceptable sections among numerous badly preserved and subaxial sections from the type locality. There are several other species, described

←Fig. 11
The most important paleoenvironmental indicator foraminifera in the studied interval of Core Rm-109 and their ecological range (Schlager 2005 facies model is applied) . a) *Ophthalmidium concentricum* (Terquem et Berthelin), 1092 m; b) *Valvulina* sp., 1086 m; c) *Mesoendothyra croatica* Gušić, 1107 m; d) *Gutnicella* gr. *cayeuxi* (Lucas), 1085.1 m; e) *Redmondoides lugeoni* (Septfontaine), 1093 m; f) *Nautiloculina oolithica* (Mohler), 1093 m; g) *Trocholina palastiniensis* Henson, 1143 m; h) *Siphovalvulina* sp., 1143 m

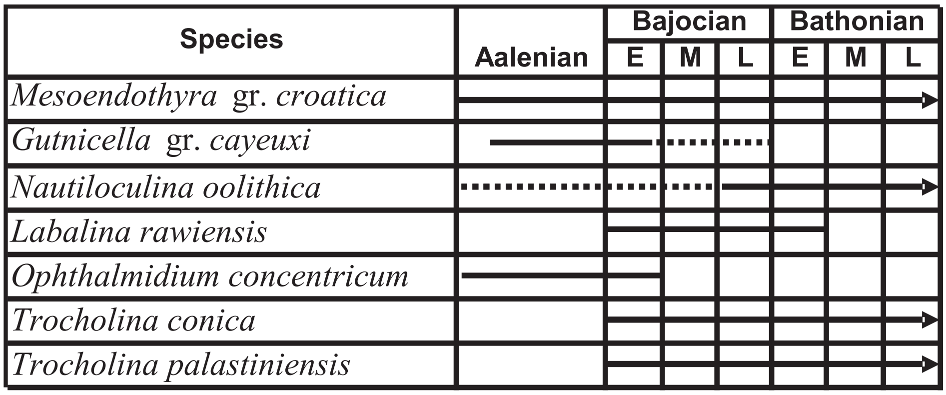


Fig. 12
Stratigraphic range of the most important species of Core Rm-109 (based on the work of Bassoullet 1998; Clerk 2005; Derin and Reiss 1965)

only on the basis of their external morphology. A similar situation exists in connection with the Upper Jurassic forms. Two species, a low and a high conical form, were determined from thin sections as *Trocholina alpina* (Leupold) and *T. elongata* (Leupold). Therefore, in our opinion, the biostratigraphic value of the trocholinas is questionable. On the other hand, each of the above-mentioned species was classified by some authors in different genera on the basis of the taxonomic concept of Neagu (1994, 1995). We followed the taxonomy of Arnaud-Vanneau et al. (1988). It is worth mentioning that we observed different wall structures of *T. conica* and *T. palastiniensis* (Fig. 10/l, m, n), respectively in the same thin section, presumably due to their different wall composition. Further investigation is needed to understand this phenomenon.

The microgranular *Nautiloculina oolithica* (Mohler) and *Mesoendothyra croatica* Gušic have a wide stratigraphic range from the Middle to the Upper Jurassic (Bassoullet 1998).

Gutnicella cayeuxi (Lucas), which appears in the uppermost part of the foraminifera-bearing interval (1085.1 m), is the only really good age-indicating species, of Aalenian–Bajocian range (Fig. 12). The Early Bajocian–Early Bathonian Labalina rawiensis (Pazdrowa) and the Aalenian–Early Bajocian Ophthalmidium concentricum (Terquem and Berthelin) confirm an Early Bajocian age (Clerc 2005).

In summary, on the basis of the foraminifer assemblage the most probable age of the studied carbonate interval is Early Bajocian (Fig. 12).

Four samples of bluish-gray siliceous shale that overlies the carbonate interval (Fig. 3) were investigated for radiolarians. Samples were disaggregated using concentrated H_2O_2 and 5% hydrofluoric acid. Only Sample 12, from 1001.65–1001.75 m, yielded a rather poorly preserved radiolarian assemblage, mainly characterized by nassellarians. The following taxa were identified from this sample: *Archaeodictyomitra* (?) *amabilis* Aita, *Archaeodictyomitra* sp., *Stichocapsa robust*a Matsuoka, *Pseudodictyomitra primitiva* Matsuoka and Yao, *Dictyomitrella* (?) *kamoensis* Mizutani et Kido, *Tricalocapsa* sp., *Stichocapsa* sp. cf. *S. japonica* Yao, *Cinguloturris* sp. cf. *carpathica* Dumitrica, et *Parvicingula* (?) sp., aff. *Parvicingula* (?) sp. A (in Baumgartner et al. 1995). The co-occurrence of *Dictyomitrella* (?) *kamoensis*, *Stichocapsa robusta*, *Archaeodictyomitra* (?) *amabilis* and *Pseudodictyomitra primitiva* indicates that this sample can be assigned to UA Zone 7 (Late Bathonian–Early Callovian age; Baumgartner 1995).

Bükkzsérc area

A quarry NW of the village of Bükkzsérc (Fig. 2) exposes the Bükkzsérc Limestone in a thickness of 20 m (Figs 13, 14). A borehole (Bükkzsérc Bzs-5) was drilled in 1984 in the yard of the quarry. It penetrated a 57 m-thick part of the

Fig. 13
Beds of the Bükkzsérc Limestone in Bükkzsérc Quarry. T marks the tectonically disturbed zone; L – lower part, U – upper part of the section displayed in Fig 14B

Bükkzsérc Limestone above the Middle to Upper Jurassic Lökvölgy Shale that belongs to the Bükk Parautochthonous Unit (Fig. 14A). A short description of the core section was presented by Pelikán and Dosztály (2000). The foraminifer fauna of Bükkzsérc Quarry and Core Bzs-5 were previously studied by Bérczi-Makk (1999) and by Bérczi-Makk et al. (1989), distinguishing *Protopeneroplis*-, *Trocholina*- and *Gutnicella*-bearing microbiofaces and determining a Bathonian–Callovian age for the succession. Most of the thin sections that were studied by Bérczi-Makk have been lost and the present investigations are based on a new series. More detailed micropaleontological and microfacies studies are under way.

In Core Bzs-5 the basal part of the Bükkzsérc Limestone is clayey and contains scattered ooid grains (Fig. 15). Poor recovery below this horizon was probably due to a karstic cavity just above the limestone-shale boundary (Figs 14A, 16A). A five-meter-thick polymict breccia bed with clasts of radiolarian wackestone,

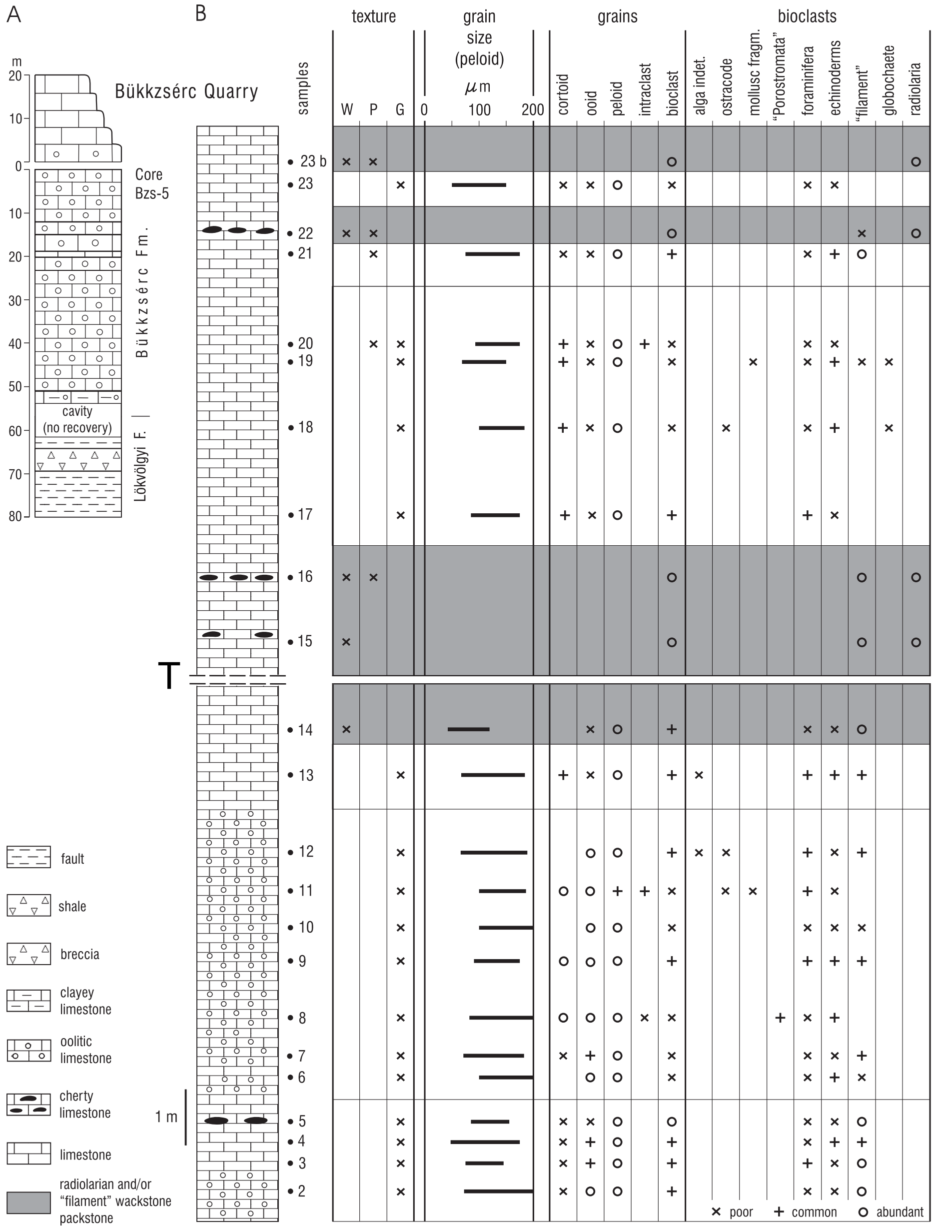


Fig. 14
A) The Bükkzsérc Limestone in Core Bzs-5 and in the Bükkzsérc Quarry (combined section); B) Geologic column of the quarry and microfacies characteristics of the succession. T marks the tectonically disturbed zone

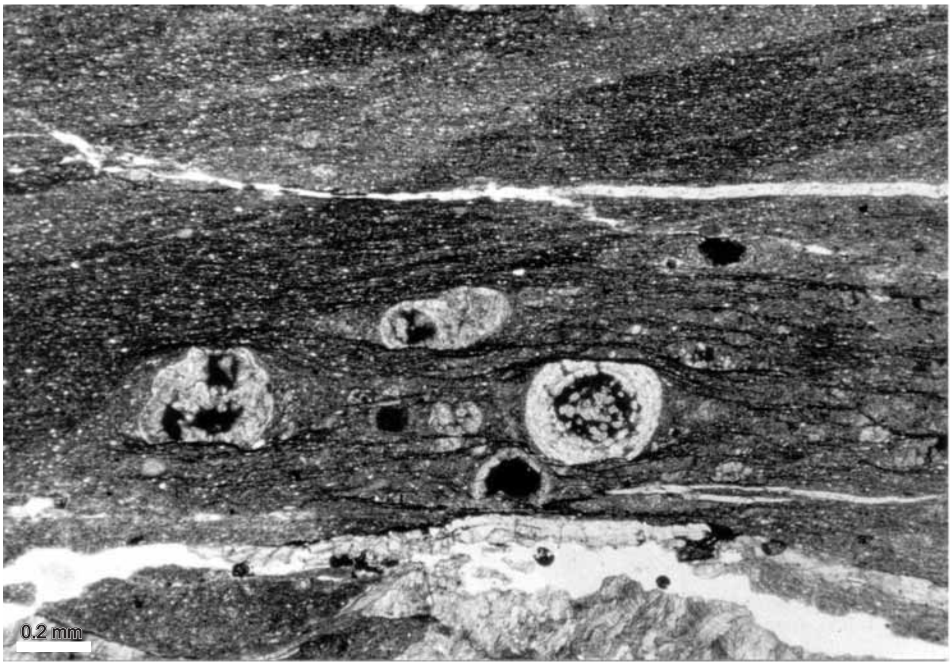


Fig. 15
Oolitic wackestone microlayer affected by dissolution cleavage in argillaceous calcisilt. Core Bzs-5, 53.3 m

radiolarite, silicified marl, peloidal wackestone and bioclastic mudstone was found below the cavity on the top of a typical shale-sandstone succession of the Lökvölgy Shale Fm.

Based on microfacies studies the penetrated succession of the Bükkzsérc Limestone can be subdivided into two parts (Fig. 16B). Oolitic grainstone, oolitic/ lithoclastic grainstone and medium- to coarse-grained calcarenite characterize the lower part of the section (Fig. 17a, b). Among the bioclasts fragments of crinoids and mollusks are predominant. Calcified cyanobacteria ("Porostromata") fragments are also common. Foraminifera occur in small or medium quantities. Bioclastic calcisilt, peloidal microsparite, "filament" wackestone, and fine-grained oolite textures were found in the carbonate lithoclasts, weathered magmatite grains also occur.

In the upper part of the core section ooids are also common but the size of the grains is significantly reduced (Fig. 16). Mudstone and wackestone-packstone texture types also appear in some layers. The typical texture types are as follows: lithoclastic, oolitic grainstone (Fig. 17/d), peloidal, oolitic grainstone, peloidal, "filament" wackestone-packstone (Fig. 17/c) and mudstone with tiny "filament" fragments. The rocks are locally partially silicified; silification of the ooid grains is especially common.

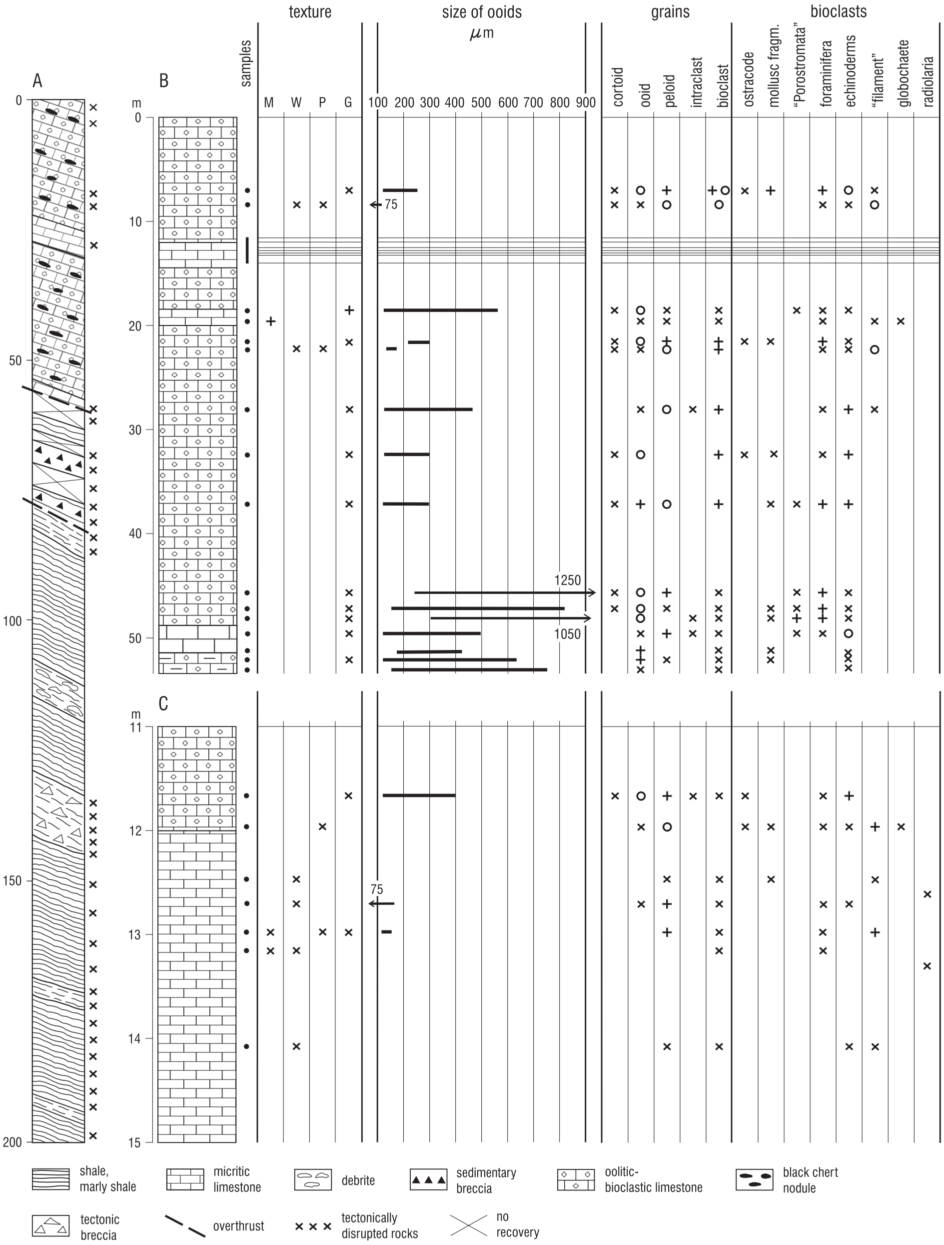


Fig. 16
A) Geologic column of Core Bzs-5; B) Microfacies characteristics of the Bükkzsérc Limestone; C) Microfacies characteristics of the densely sampled 11–15 m interval

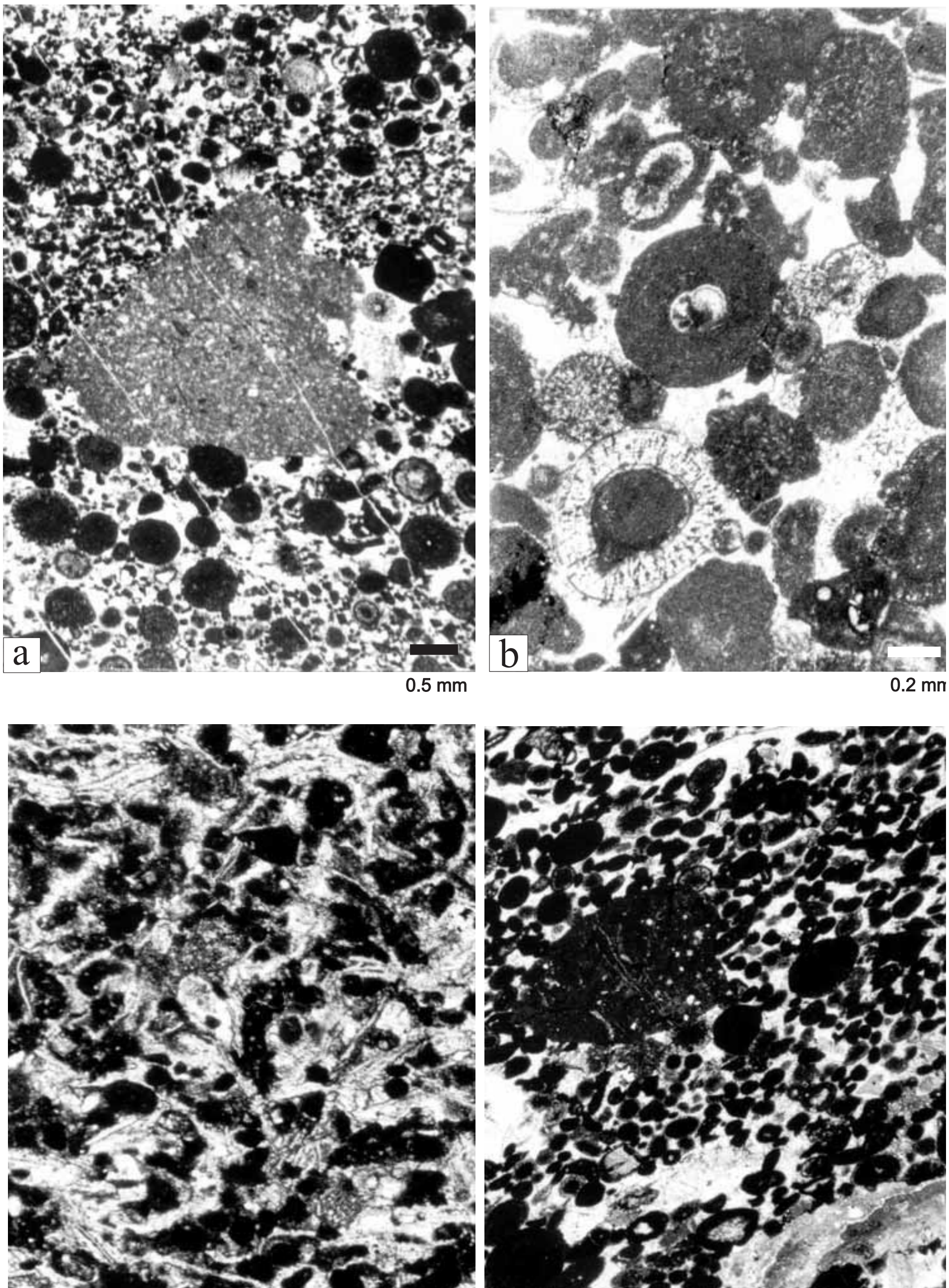


Fig. 17
Microfacies types in core Bzs-5. a) Oolitic, lithoclastic grainstone, 47.5 m; b) oolitic, oncoidal grainstone, 47.3 m; c) peloidal, "filament" packstone, 8.4 m; d) lithoclastic, oolitic grainstone, 18.7 m

The measured section of the quarry (Fig. 14/B) is the continuation of Core Bzs-5. A fault cuts through the exposed succession (Figs 13, 14/B); however, the amount of displacement is unknown. The eastern part of the quarry exposes the lower interval that is made up of thick-bedded limestone. In the western part of the quarry thick-bedded oolitic limestone occurs in the lower part of the succession. This grades upward into thin-bedded limestone with chert laminae and grayish green claystone laminae. These layers are overlain by thick beds of oolitic limestone. In the topmost part of the exposed sequence a 5 cm-thick chert layer was found.

The Bükkzsérc Limestone was also penetrated in Core Bükkzsérc Bzs-11 that was cut 3 km NE of Bükkzsérc Quarry. A 5 m-thick volcaniclastic bed (with rhyolite-dacite clasts) was found here within the 18.6 m-thick oolitic limestone unit (Pelikán and Dosztály 2000). It is underlain by a shale bed with limestone interlayers, debrites, and slump structures, radiolarite (radiolarian packstone) and partially silicified pelagic carbonates ("filament" wackestone, sponge-spicule packstone, peloidal grainstone rich in tiny foraminifera) with volcaniclastic debrite interbeds in a thickness of 100 m. Alternation of dark gray shale and sandstone characterizes the lowermost 20 m-thick part of the core.

Microfacies types of the Bükkzsérc Quarry section

The following microfacies types were distinguished:

Peloidal, oolitic, "filament" grainstone (Fig. 18a)

Grainstone, abundant in peloids, cortoids, ooids. Fragments of thin-shelled bivalves ("filaments") are abundant. It contains small or medium amounts of echinoderm detritus (predominantly benthic crinoids) and foraminifera.

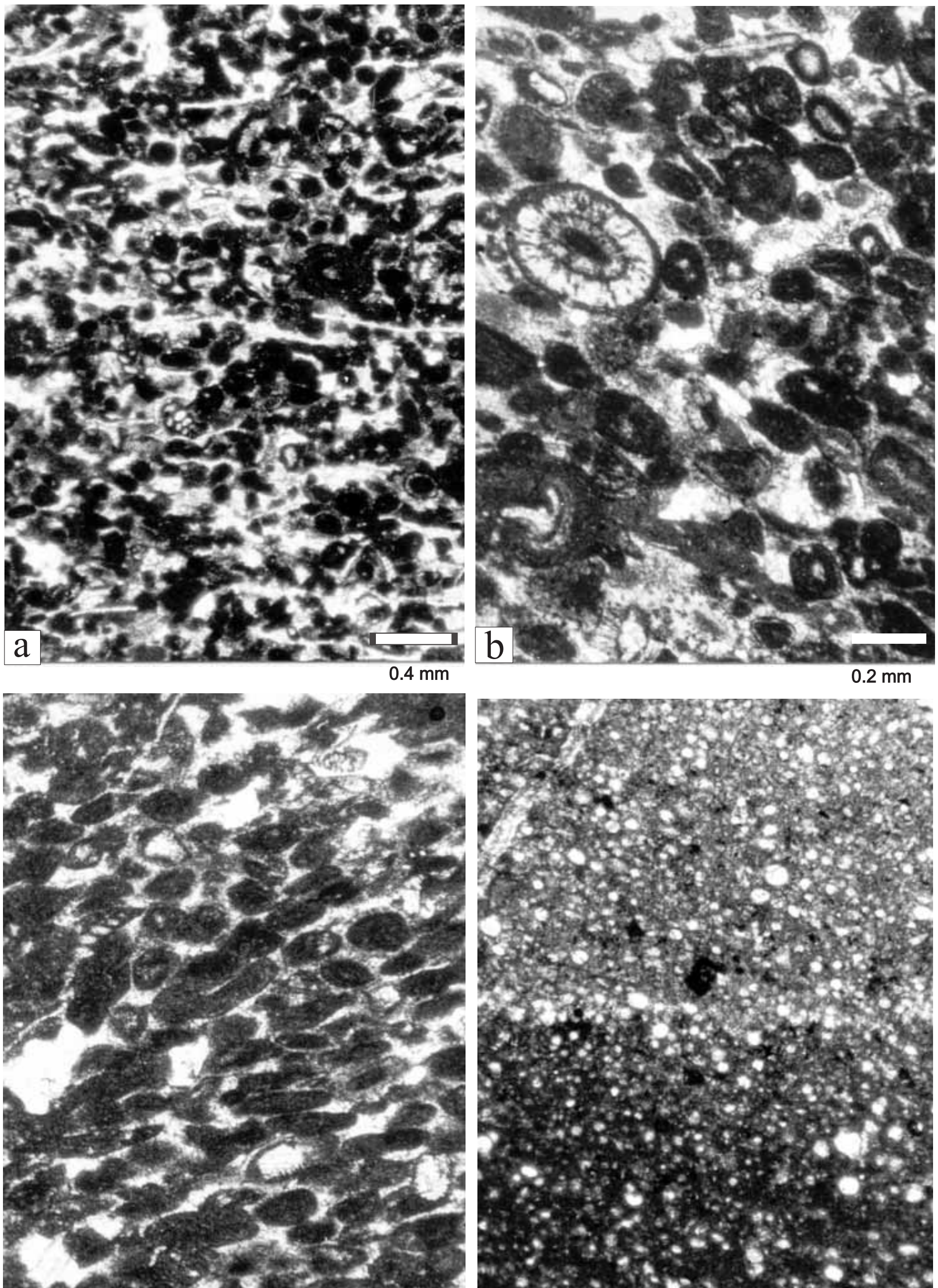
Peloidal, oolitic grainstone (Fig. 18b)

Grainstone, abundant in peloids, ooids and cortoids; small lithoclasts also occur in some beds. Fragments of thin-shelled bivalves are rare or absent, echinoderm (crinoid) detritus and foraminifera usually are present in small or medium quantities. Fragments of "Porostromata" were found in a single bed only.

Peloidal grainstone (Fig. 18c)

In this grainstone peloid grains are predominant; cortoids and ooids also occur but only in small to medium amounts. Fragments of thin-shelled bivalves are usually absent whereas detritus of echinoderms (crinoids) and foraminifera generally occur.

Fig. 18 →
Microfacies types in the section of Bükkzsérc Quarry. a) Peloidal, oolitic, "filament" grainstone, Sample 2; b) Peloidal, oolitic grainstone, Sample 11; c) Peloidal grainstone, Sample 18. Note tectonic elongation of the originally globular grains in sample 11 and 18; d) Radiolarian wackestone, Sample 15


a
0.4 mm
b
0.2 mm
c
0.2 mm
d
0.4 mm

Peloidal "filament" wackestone

Wackestone abundant in peloids, cortoids and ooids occurs commonly. Fragments of thin-shelled bivalves are abundant; echinoderm detritus and foraminifera are also present.

Radiolarian wackestone (Fig. 18d)

Wackestone abundant in calcitic molds of radiolarians; fragments of thin-shelled bivalves are common.

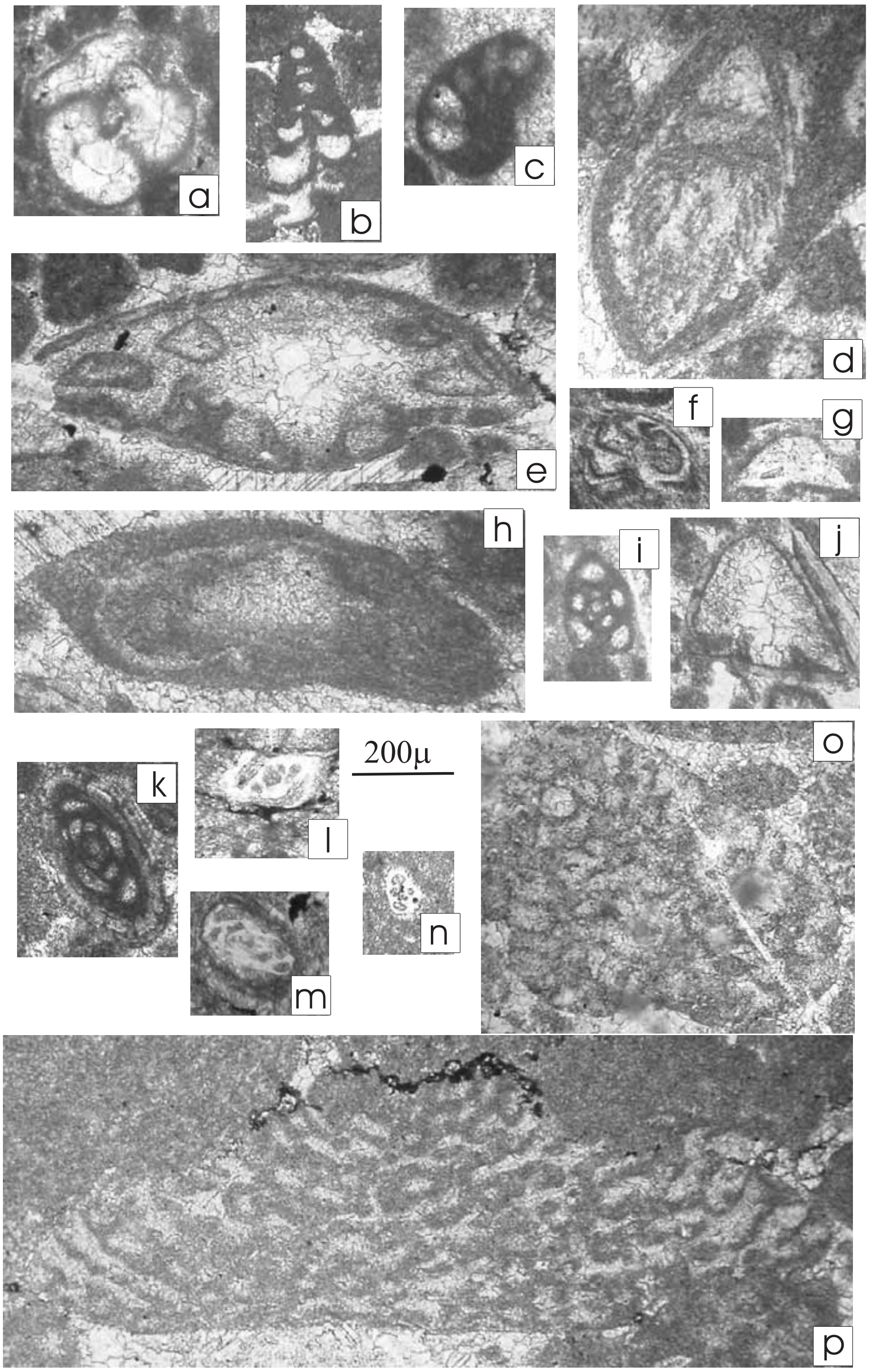
The succession of the microfacies types is presented in Fig. 14/B. In the lowermost part of the section peloidal, oolitic grainstone texture is typical, similar to that in the uppermost part of core Bzs-5. This is followed by an oolitic, peloidal grainstone interval. Grading was observed in Sample 10 only. Peloidal, "filament" wackestone was found just below the fault zone, and radiolarian "filament" wackestone occurs on the other side of the fault. This suggests only moderate displacement along the fault that does not disturb the general upward-deepening facies trend. In the upper part of the succession peloidal grainstone, peloidal "filament" wackestone and radiolarian wackestone alternate. The topmost bed is made up predominantly of calcified radiolarians.

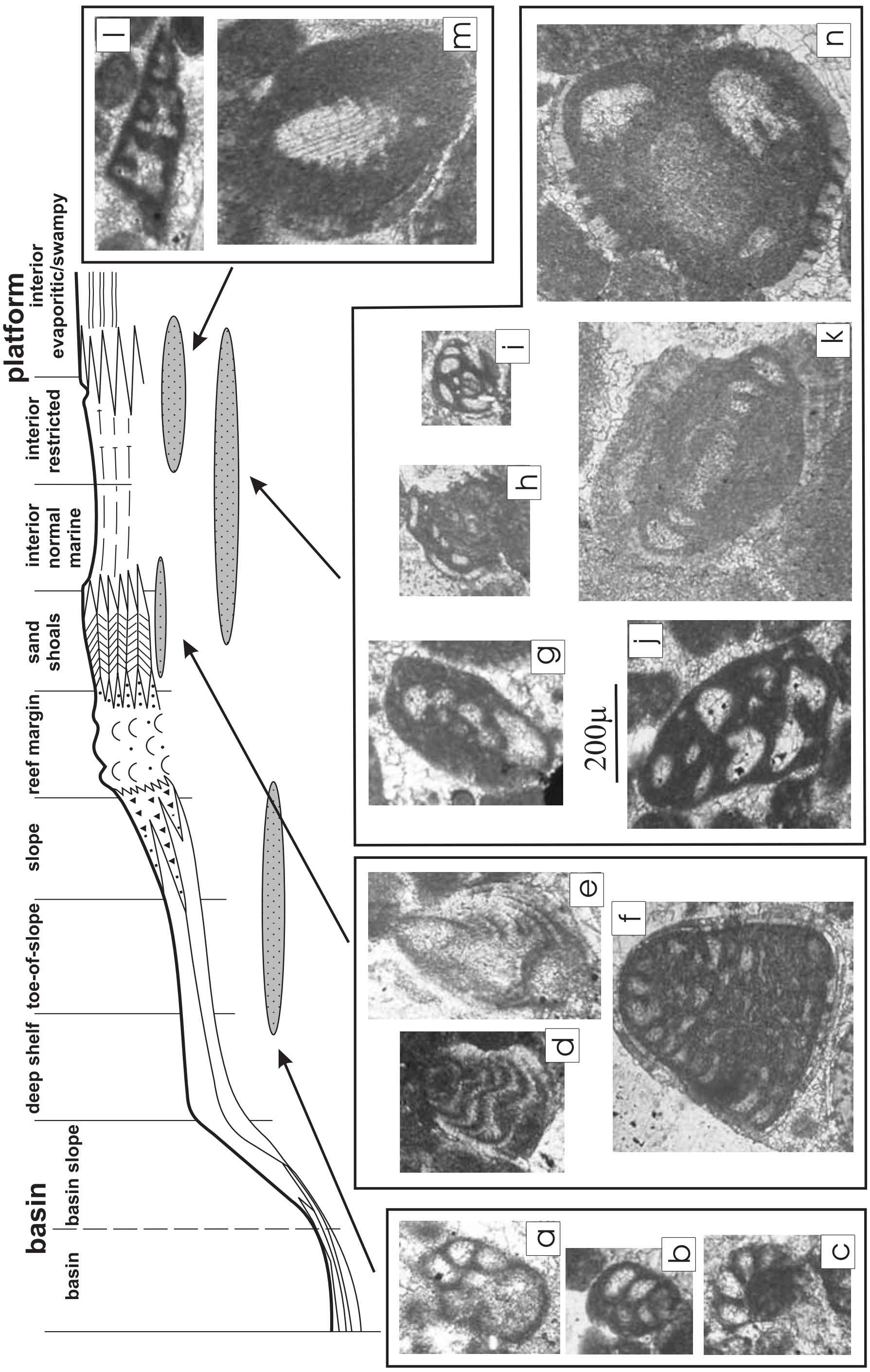
Interpretation of the source area of the carbonate particles and depositional environment

The coated grains (cortoids, ooids), which are characteristic and common constituents of the Bükkzsérc Limestone were derived from a carbonate platform. The polygenetic peloids are predominantly of shallow marine origin as well.

The most characteristic foraminifera of the Bükkzsérc Limestone as studied in this area are shown in Fig. 19. The habitats of the most typical forms are presented in Fig. 20. Similarly to the foraminifer fauna found in Core Rm-109 the agglutinated forms are also predominant throughout the succession. The

Fig. 19 →
Characteristic foraminifera of the Bükkzsérc Limestone in Core Bzs-5 and in the section of Bükkzsérc Quarry. a) *Siphovalvulina* sp. (Sample 21, Bükkzsérc Quarry); b) *Riyadella* sp. (47.3 m, Core Bzs-5); c.) *Callorbis minor* Wernli et Metzger (Sample 13, Bükkzsérc Quarry); d) *Protopeneroplis striata* Weynschenk (32.4 m, Core Bzs-5); e) *Trocholina conica* (Schlumberger) (18.7 m, Core Bzs-5); f) *Archaeosepta platierensis* Wernli (Sample 8, Bükkzsérc Quarry); g) *Paalzowella feifeli feifeli* (Paalzow) (Sample 21, Bükkzsérc Quarry); h) *Trocholina* sp. A. (37.8 m, Core Bzs-5); i) *Labalina rawiensis* (Pazdrowa) (Sample 8, Bükkzsérc Quarry); j) *Trocholina* sp. B. (21.5 m, Core Bzs-5); k) *Labalina quinqueloculinoides* (Danitch), (Sample 11, Bükkzsérc Quarry); l.-m) *Labalina rawiensis* (Pazdrowa) (=*Involutina*" bükki Bérczi-Makk) (21.8 m, Core Bzs-5); n) *Labalina rawiensis* (Pazdrowa) (=*Involutina*" bükki Bérczi-Makk) (13.2 m, Core Bzs-5); o) *Gutnicella. bizonorum* (Bourrouilh et Moullade) (45.7 m, Core Bzs-5); p) *G. cayeuxi* (Lucas) (47.3 m, Core Bzs-5)


a
b
c
d
e
f
g
h
i
j
k
l
200µ
m
n
o
p


platform
interior evaporitic/swampy
interior restricted
interior normal marine
sand shoals
reef margin
slope
toe-of-slope
deep shelf
basin
basin slope
basin
200μ
a
b
c
d
e
f
g
h
i
j
k
l
m
n

Textularia–Valvulina–Trocholina (TVT) group is the most common, especially at 18.7–49.2 m in core Bzs-5 and samples 17–20 in the quarry section. Beside them other smaller agglutinated forms, like *Verneuilinoides* spp., *Siphovalvulina* spp., *Haplophragmoides* spp. and *Callorbis minor* Wernli et Metzger are also common elements of the fauna. These foraminifera are characteristic of the outer platform. In the lower part of the section (51.9–45.7 m) larger agglutinated forms, namely *Gutnicella cayeuxi* (Lucas), *G. bizonorum* (Bourrouilh et Moullade) and *G. minoricenzis* (Bourrouilh et Moullade) are very abundant, but a few specimens of *Riyadella* spp. and *Redmondoides* gr. *lugeoni* also occur. The *Gutnicella cayeuxi* group is typical for the outer platform ooid shoal environment, as are small foraminifera of a special double-layered structure, such as *Protopeneroplis striata* Weynschenk and *Archaeosepta platierensis* Wernli, which commonly occur in the succession. The inner platform elements such as species of *Trocholina* (*Trocholina conica, T. palastiniensis, T*. sp.), *Paalzowella feifeli feifeli* (Paalzow), *Spirillina* sp. and *Epistomina* sp. are less frequent and appear mostly in two levels (at 18.7–49.2 m in core Bzs-5 and in samples 17–20 of the quarry section). The porcelanous miliolinae occur throughout the section, but most frequently in its lower part. *Labalina rawiensis, L. quinqueloculinoides* (Danitch), *Ophthalmidium terquemi* Pazdrowa, *O. caucasicum* (Antonova), and *Nubecularia reicheli* Rat are of inner to middle platform origin. Between 12.4 and 14.0 m a monospecific foraminifer fauna occurs in strongly silicified layers, consisting of *L. rawiensis* (previously identified as "*Involutina*" *bukki* Bérczi-Makk).

In one layer (Sample 13 of the quarry section) algae *Pseudolithocodium carpathicum* Misik are relatively common. The rare "Porostromata" remains are also derived from the platform margin. The upper foreslope may have been the habitat of the crinoids, i.e. the source of crinoid sand. The thin-shelled bivalves and radiolarians are pelagic elements of the sediment, that is, products of a "pelagic factory".

In summary, the coated grains, probably a large part of the peloids and the bioclasts are derived from a carbonate platform and platform foreslope. Toe-of-slope and pelagic basin were the depositional environment, where the redeposited fine carbonate sand and the *in situ* deposited biogenic grains were accumulated. The predominant grainstone texture suggests current-agitated,

←Fig. 20
The most important paleoenvironmental indicator foraminifera of the Bükkzsérc Limestone in Core Bzs-5 and in the section of Bükkzsérc Quarry, and their ecological range (Schlager 2005 facies model was applied). a) *Trochammnina* sp. (Sample 12, Bükkzsérc Quarry); b) *Textularia* sp. (7.1 m, Core Bzs-5); c) *Callorbis minor* Wernli et Metzger (28.6 m, Core Bzs-5); d) *Archaeosepta platierensis* Wernli (Sample 11, Bükkzsérc Quarry); e) *Protopeneroplis striata* Weynschenk (7.1 m, Core Bzs-5); f) *G. minoricenzis* (Bourrouilh et Moullade) (45.7 m, Core Bzs-5); g) *Mesoendothyra croatica* Gušić (45.7 m, Core Bzs-5); h) *Nubecularia reicheli* Rat (47.3 m, Core Bzs-5); i) *Labalina rawiensis* (Pazdrowa) (7.1 m, Core Bzs-5); j) *Riyadella* sp. (37.3 m, Core Bzs-5); k) *Nautiloculina oolithica* (Mohler), (47.3 m, Core Bzs-5); l) *Pseudolithocodium carpathicum*, Misik (Sample 13, Bükkzsérc Quarry); m) *Trocholina palastiniensis* Henson (high-form) (18.7 m, Core Bzs-5); n) *Redmondoides lugeoni* (Septfontaine) (47.3 m, Core Bzs-5)

high-energy environment whereas the wackestone was probably deposited in a low-energy environment.

Biostratigraphy

The biostratigraphic evaluation of the Bükkzsérc Limestone in the studied sections is based on the foraminifer fauna. Age-diagnostic radiolarians were encountered in silicified rocks beneath the Bükkzsérc Limestone. However, these data do not provide direct information on the age of the Bükkzsérc Limestone itself, characteristics of its contact with the underlying formation must be taken into consideration.

The stratigraphic ranges of the most important foraminifer species of the Bükkzsérc section (Core Bzs-5 and Bükkzsérc Quarry) are presented in Fig. 21. Aalenian–Late Bajocian *Gutnicella* gr. *cayeuxi* occur only in the lowermost foraminifer-bearing layers (Bzs-5 51.9–45.7 m). Early to Late Bajocian *Callorbis minor* first appear at 32.4 m of Core Bzs-5 and their last occurrence is observed in Sample 13 of the quarry. In Samples 8 to 13 of the quarry the important age-diagnostic Late Bajocian–Bathonian *Archaeosepta platierensis* occurs. This species prefers the same facies as *Protopeneroplis striata* that was found throughout the section. Therefore the presence or absence of *A. platierensis* is likely age-controlled.

The lowermost part of the section, below 32.4 m of Core Bzs-5, is most probably Aalenian? or Early Bajocian in age. The next interval, up to Sample 8 of the quarry, is probably of Middle Bajocian age. From the first occurrence of *A.*

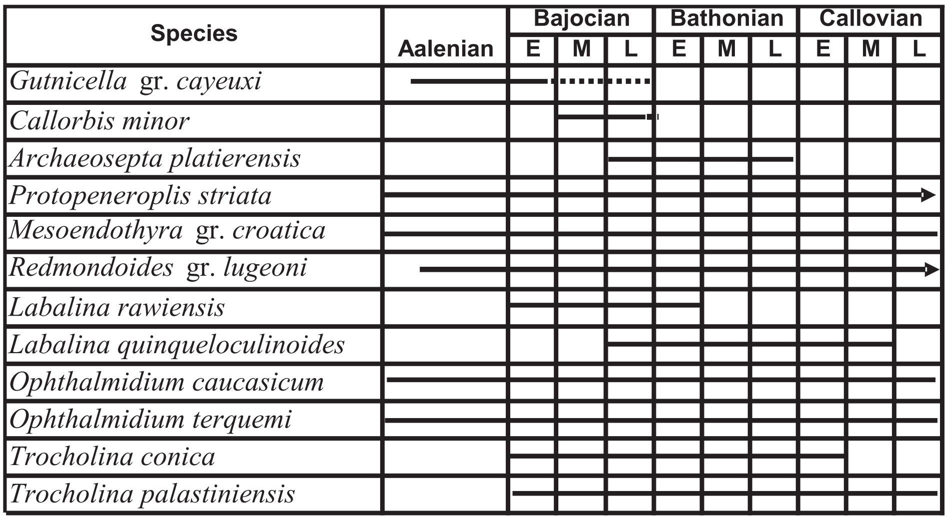


Fig. 21
Stratigraphic range of the most important species of Bükkzsérc Quarry and Core Bzs-5 (based on the work of Bassoullet 1998; Clerk 2005; Derin and Reiss 1965)

platierensis the layers are not older than Late Bajocian. Based upon Sample 13 the age of the beds is probably Late Bathonian, but a Callovian age could not be excluded.

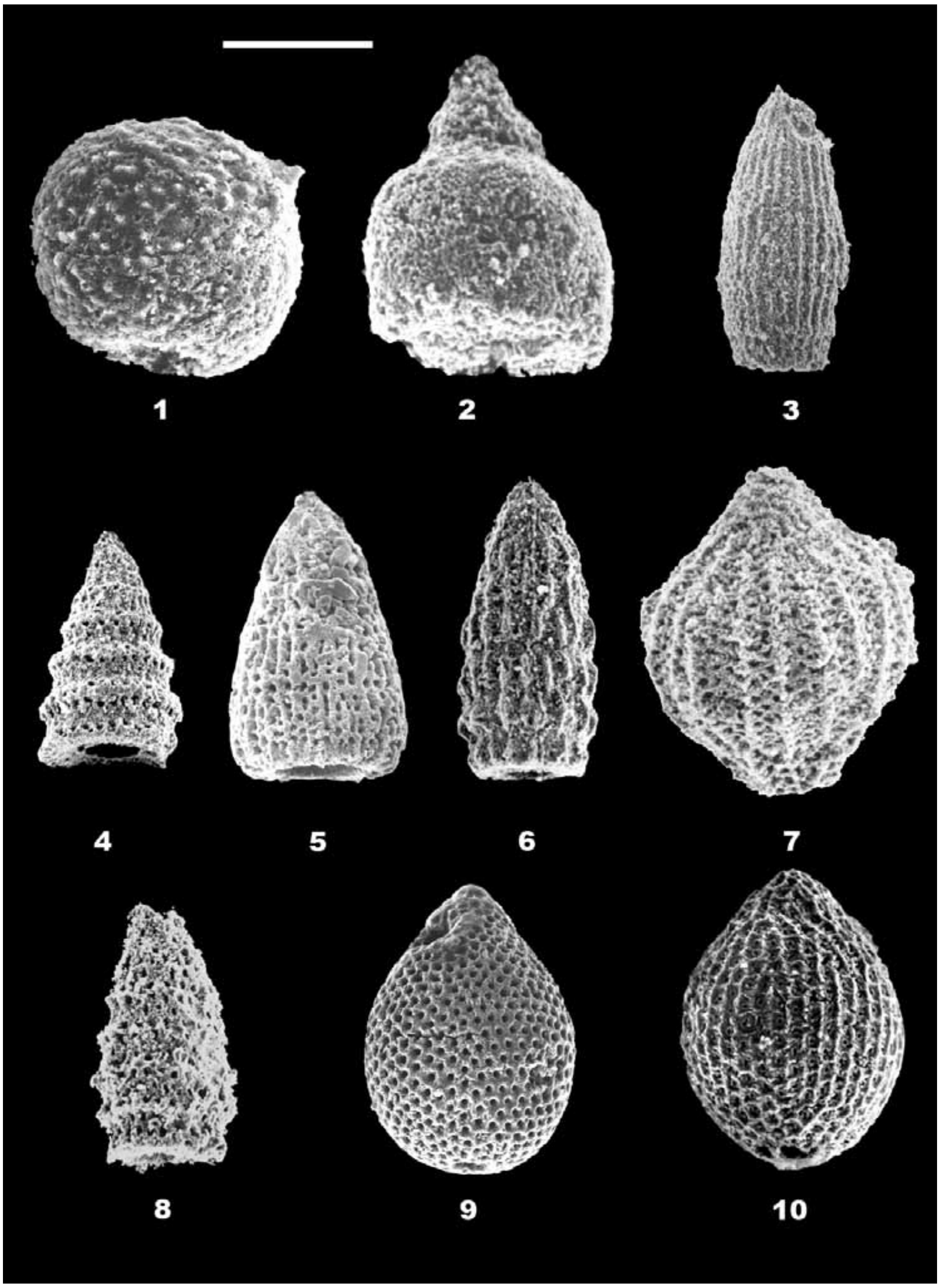
In summary, on the basis of the distribution of the foraminifer species a continuous succession is exposed in Core Bzs-5 and Bükkzsérc Quarry, representing an interval from the Aalenian? or Early Bajocian to the Bathonian.

The first studies of radiolarians of the Bükkzsérc boreholes were performed by Dosztály (1991, 1997), Csontos et al. (1991a) and Pelikán and Dosztály (2000). The samples were collected from a breccia bed beneath the oolitic Bükkzsérc Limestone in Core Bzs-5 (66.7 m), and from chert and silicified pelagic limestone underlying the Bükkzsérc Limestone in core Bzs-11. Based on these investigations a Late Bajocian–Early Bathonian age was determined for both the radiolarite clasts in the sedimentary breccia in core Bzs-5 and the radiolarian-bearing horizons in Core Bzs-11.

In the course of the present studies, a sample taken from the above-mentioned radiolarite breccia bed at 66.7 m of Core Bzs-5 yielded a moderately poorly-preserved radiolarian fauna, characterized mostly by nassellarians. The following taxa were identified (Fig. 22): *Eucyrtidiellum* sp., *Archaeodictyomitra exigua* Blome, *Dictyomitrella* (?) *kamoensis* Mizutani and Kido, *Tricalocapsa* (?) *fusiformis* Yao *T*. (?) aff. *fusiformis*, *Transhsuum maxwelli* (Pessagno), *Protunuma* sp., *Unuma* spp., *Parvicingula dhimaensis dhimaensis* Baumgartner and *Stichocapsa convexa* Yao. Based on the presence of *T. maxwelli* and *P. dhimaensis dhimaensis* this assemblage can be assigned to UA Zones 3–11 (Baumgartner et al. 1995). *D*. (?) *kamoensis* indicates UA Zones 3–7. The biostratigraphic range of *S. convexa* indicates UA Zones 4–7 and *T*. (?) *fusiformis* indicates UA Zones 3–5. It follows that the co-occurrence of *D*. (?) *kamoensis, T.* (?) *fusiformis* and *S. convexa* indicates UA Zones 4–5 (Baumgartner et al. 1995). Therefore the radiolarite clasts at 66.7 m of Bzs-5 are certainly of Late Bajocian to Early Bathonian age. This means that the age of the matrix and consequently the age of deposition of the sedimentary breccia bed must be somewhat younger.

In Core Bzs-11 samples were taken from 42.8 m, 60.0 m, 66.5 m and 78.7 m (Fig. 21). The following taxa were identified from 42.8 m: *Hsuum* spp. ?*Parahsuum* sp., *Transhsuum maxwelli*, *Stichocapsa robusta* Matsuoka and *Tricolocapsa* cf. *plicarum* Yao. The co-occurrence of *S. robusta* and *T. maxwelli* indicates that this sample can be assigned to UA Zones 5–7 (Early Bathonian–Early Callovian age).

Fig. 22 ⟶
Radiolarians from Cores Bzs-5 and Bzs-11. 1. *Praewilliridellum spinosum* Kozur, Bzs-11 (66.5 m), scale = 85 μm; 2. *Eucyrtidiellum* sp., Bzs-5 (66.7 m), scale = 95 μm; 3. *Archaeodictyomitra exigua* Blome, Bzs-5 (66.7 m), scale = 75 μm; 4. *Dictyomitrella* (?) *kamoensis* Mizutani et Kido, Bzs-5 (66.7 m), scale = 95 μm; 5. *Hsuum* sp., Bzs-11 (78.7 m), scale = 100 μm; 6. *Transhsuum maxwelli* (Pessagno), Bzs-5 (66.7 m), scale = 75 μm; 7. Unuma sp., Bzs-5 (66.7 m), scale = 80 μm; 8. *Parvicingula dhimaensis dhimaensis* Baumgartner, Bzs-5 (66.7 m), scale = 90 μm; 9. *Stichocapsa robusta* Matsuoka, Bzs-11 (78.7 m), scale = 80 μm; 10. *Tricolocapsa conexa* Matsuoka, Bzs-11 (78.7 m), scale = 80 μm


1
2
3
4
5
6
7
8
9
10

The sample from 60.0 m yielded a poorly-preserved and low-diversity radiolarian fauna. The following taxa were identified: *Archaeodictyomitra* sp., *Parahsuum* sp. *Stichocapsa robusta*, and *Tricolocapsa* cf. *plicarum*. *S. robusta* indicates UA Zones 5–7; therefore the sample is of Early Bathonian to Early Callovian age.

The sample from 66.5 m yielded a moderately well-preserved and high-diversity radiolarian fauna: *Praeconocaryomma* (?) sp., *Praewilliridellum spinosum* Kozur, *Williridellum* sp., *Archaeodictyomitra* sp., *Hsuum* spp., *Parahsuum* sp., *Transhsuum maxwelli, Parvicingula* sp. and *Stichocapsa robusta* Matsuoka. The biostratigraphic range of *T. maxwelli* indicates UA Zones 3–11 and that of *S. robusta* UA Zones 5–7. *P. spinosum* has only been reported from the Middle Bajocian (Kozur 1984). However, this species is known only from Csipkés-tető (southern Bükk Mts) and an undefined section of the Telekes valley (Rudabánya Mts). It is thus possible that it has a wider biostratigraphic range. In conclusion, the sample from 66.5 m can be assigned to UA Zones 5–7 (Late Bathonian to Early Callovian age).

The sample from 78.7 m contains a poorly-preserved and low-diversity radiolarian fauna. The following taxa were identified: *Sethocapsa* sp., *Hsuum* spp., *Transhsuum* sp., *Stichocapsa robusta, Stichocap*sa spp. and *Tricolocapsa conexa* Matsuoka. The biostratigraphic range of *S. robusta* indicates UA Zones 5–7 and *T. conexa* points to UA Zones 4–7. Consequently their co-occurrence indicates UA Zones 5–7 (Late Bathonian to Early Callovian age).

In summary the age of the radiolaritic chert and partially silicified pelagic carbonates which occur below the Bükkzsérc Limestone is Late Bathonian to Early Callovian. This means that the deposition of the breccia bed in Core Bzs-5 was roughly coeval with deposition of this succession. Taking into account that the foraminiferan biostratigraphic age of the basal part of the Bükkzsérc Limestone is Aalenian? or Early Bajocian in Core Bzs-5, a tectonic contact must be assumed between the Bükkzsérc Limestone and the breccia bed. Significantly, in large parts of the Bükk Mts (in the area of the Bükk Parautochthonous Unit – Csontos et al. 1991b; Csontos 2000), Triassic formations of various facies are overlain by radiolarite (Bányahegy Radiolarite Formation of Callovian to Kimmeridgian age; Csontos et al. 1991b). Thus the deposition of the Bükkzsérc Limestone would be coeval with the sedimentary gap in the Bükk Parautochthonous Unit, which confirms the concept that the Bükkzsérc Limestone belongs to another structural unit, i.e. a nappe that was overthrust onto the parautochthonous unit.

Origin of the studied Jurassic carbonates

The present-day setting of the studied Jurassic sequences is the result of multiple sedimentological processes and tectonic displacements. The carbonate succession of Core Rm-109 in the Mátra Mts, and of the Bükkzsérc Limestone in the Bükk Mts, is made up of constituents of a Jurassic accretionary complex that was affected by structural deformation and metamorphism during the Late Jurassic to Early Cretaceous, and large-scale tectonic displacements in the Tertiary. For the interpretation of the geodynamic history of the Pannonian region, determination of the original paleogeographic setting of these rock bodies is crucial.

The opening of the Vardar (or Dinaridic; Pamić 2003) branch of the western Neotethys Ocean began in the Middle Triassic. Continuation of the Neotethys spreading and onset of opening of the new Ligurian–Piedmont–Penninic oceanic branch led to the disruption of formerly widely extended carbonate platforms in the area between the two oceanic basins in the Early Jurassic. The combined effect of the enhanced, although differentiated sinking of the disintegrated former platforms and a long-term sea level rise led to step-by-step drowning of the carbonate platforms almost everywhere in this region, from the latest Triassic to the Toarcian. The Adriatic (or Adriatic–Dinaridic; Bucković et al. 2004) Carbonate Platform (ADCP) was the only exception in the wider region where shallow marine conditions prevailed as late as till the end of the Cretaceous (Dragičević and Velić 2002). Consequently, it is highly probable that the Middle Jurassic redeposited carbonates exposed in Core Rm-109 and the Bükkzsérc Limestone in the Bükk Mts were derived from an area located in the neighborhood of the ADCP.

Comprehensive paleogeographic studies have interpreted the setting of facies zones of the ADCP for the Jurassic and outlined the platform margin and the slope faces (Dozet and Šribar 1998; Tilšjar and Velić 1991; Dragičević and Velić 2002). In the Middle Jurassic, ooid shoals were formed along the platform margin and relatively large islands came into existence. In the Late Jurassic, coral-stromatoporoid reefs are characteristic for the margin and oolites are less common. Stromatoporids, sponges, bryozoans, corals, calcareous algae, gastropods, bivalves, echinoids and benthic foraminifera are reported from the reef facies (Turnšek 1966; Turnšek et al. 1981; Leinfelder et al. 2005). Slope deposits and, in the proximal basin, sediments containing larger blocks and clasts of reefs were also reported (Dragičević and Velić 2002).

The definite similarity of the foraminifer fauna of the Middle Jurassic of the ADCP and the studied carbonates in NE Hungary confirms their close paleogeographic relations.

Cyanobacterial remnants ("Porostromata") are characteristic and common biogenic elements of the carbonate succession of Core Rm-109. Therefore the occurrence of these fossils in the Middle Jurassic of the ADCP is crucial for the evaluation of the provenance of the redeposited carbonates. The classification and terminology of "Porostromata" have been significantly altered in the past decades. A classification of numerous forms that were previously assigned to the calcareous algae (*Codiacea* group; *Cayeuxia*, *Ortonella*, *Hedstroemia*, etc.) has been revised. Comparative studies of recent cyanobacteria (*Rivularia, Scytonema*) and fossil calcareous filamentous remnants revealed their significant similarity

(Dragastan et al. 1996). Accordingly, at present those remnants that used to be classified within the group "Porostromata" (Pia 1927), along with other calcareous filamentous fossils, are considered as calcified cyanobacteria (Riding 1992; Pentecost 1991; Portman et al. 2005). In studies of the Jurassic facies of the ADCP such remnants were classified in the group of calcareous algae, either as Cyanophyta, Codiaceae or other taxa (Radoičić 1966; Dozet and Šribar 1998; Dragičević and Velić 2002). According to Radoičić (1966) the Codiaceae (Cayeuxia, Ortonella, etc.) are abundant in the late Dogger to early Malm interval. The rich photomicrograph illustration of her comprehensive monograph permits the identification of these remnants that could be classified within the "Porostromata" group although she did not use this term. The abundance of calcified cyanobacteria ("Porostromata") fragments in the resedimented carbonates in our study supports the link to the ADCP as provenance.

Considering that no carbonate platform survived the intense relative sea level rise prior to the Middle Jurassic in the wider region except the ADCP, it is highly probable that the ADCP was the source of the redeposited carbonates. The platform foreslopes and the periplatform basins (Slovenian Trough, Bosnian Flysch Basin) must have been sites of deposition. Subduction and related accretionary wedge formation began in the Middle Jurassic and continued in the Late Jurassic in the northwestern part of the Vardar (Dinaridic) oceanic branch (Halamić et al. 2005). Triassic and Jurassic radiolarian chert, redeposited carbonates and siliciclastics (shale, siltstone and sandstone) and magmatic rocks were incorporated into the accretionary complex. The overthrust of the accretionary complex onto the subsided Bükk Parautochthonous Unit also took place during the Late Jurassic (Csontos 1999; Csontos and Vörös 2004). It was followed by multistage tectonic deformation and very low-grade regional metamorphism of the parautochthonous unit and the nappes in the Early Cretaceous. Right-lateral shear along the Mid-Hungarian Zone led to large-scale displacement of the entire Bükk Unit (including the Darnó Complex) in the Late Paleocene to Early Miocene (Csontos et al. 1992; Haas and Kovács 2001; Csontos and Vörös 2004). Remnants of the Jurassic accretionary wedge of the Vardar oceanic branch, very similar to those in the Darnó and Szarvaskő Complexes, are known in the Medvednica and the Kalnik Mts in Croatia (Pamić 1997, 2003; Pamić et al. 2002; Halamić et al. 2005). Along with basalts Triassic and Jurassic radiolarian chert and calpionellid limestone were reported from the Medvednica Mts, but no Jurassic redeposited limestone of carbonate platform origin has been encountered (Halamić and Goričan 1995; Halamić et al. 2005). Beside shale and sandstone, micritic and calcarenitic limestone were reported from the Kalnik Mts (Pamić 1997).

Conclusions

1. Aalenian? or Early Bajocian carbonates of lower platform foreslope, proximal and distal toe-of-slope facies that are overlain by Bathonian to Callovian shale were encountered in Core Recsk Rm-109, in the Mátra Mts.

2. Early Bajocian to Bathonian carbonates (Bükkzsérc Limestone Fm.) of distal toe-of-slope and basin facies occur in the in the Bükkzsérc section (Core Bzs-5 and quarry) in the Bükk Mts.

3. Middle Jurassic redeposited carbonates of similar facies were reported from the margin of the Adriatic Carbonate Platform and from the Slovenian Trough and Bosnian Flysch Zone that were located in the neighborhood of the ADCP, and served as the depositional area of the platform-derived carbonate sediments during the Jurassic.

4. Since no other carbonate platform survived the intense relative sea level rise in the Middle Jurassic in the region except the ADCP, this platform must have been the source of the redeposited carbonates, and the neighboring slopes and basins were the sites of redeposition. Accretionary wedge formation began in the Middle to Late Jurassic. It was followed by multistage tectonic deformation and very low-grade regional metamorphism of the parautochthonous unit and the nappes in the Late Jurassic to Early Cretaceous, and large-scale horizontal displacement of the Bükk Unit during the Early Tertiary.

Acknowledgements

The authors are indebted to referees László Csontos and József Pálfy for their comments and suggestions. This work was supported by the Hungarian Scientific Research Fund (OTKA) projects No. T 047121, K61872 and F048341.

References

Arnaud-Vanneau, A., T. Boisseau, C. Darsac 1988: Le genre Trocholina PAALZOW 1922 et ses principales espèces au Crétacé. – Rev. Paléobiol., vol. Spéc. 2, Benthos'86, Genève, pp. 353–377.

Balla, Z. 1983: Stratigraphy and tectonics of the Szarvaskő synform, Bükk Mts, North Hungary. – Magyar Állami Eötvös Loránd Geofizikai Intézet 1985. évi jelentése, pp. 42–65.

Balla, Z., Cs. Baksa, J. Földessy, L. Havas, I. Szabó 1980: The tectonic setting of the ophiolites in the Bükk mountains (North Hungary). – Geol. Zborn. – Geol. Carpath., 31, pp. 465–493.

Balla, Z., D.M. Hovorka, M. Kuzmin, V.I. Vinogradov 1983: Mesozoic ophiolites of the Bükk Mountains (North Hungary). – Ofioliti, 8, pp. 5–46, Bologna.

Balogh, K. 1964: Die geologischen Bildungen des Bükk-Gebirges. – Annales Inst. Geol. Publ. Hung., 48, pp. 245–553.

Balogh, K., H. Kozur, P. Pelikán 1984: Die Deckenstruktur des Bükkgebirges. – Geol. Paläont. Mitt., Innsbruck, 13, pp. 89–96.

Bassoullet, J-P. 1998: Foraminifères. Les grands foraminifers. – In: Graciansky de, P.C., J., Hardenbohl, T., Jacquin, P.R. Vail: Mesozoic and Cenozoic sequence stratigraphy of European basins. – Soc. Econ. Paleont. Miner., Spec. Pub., 60. pp. 293–304.

Baumgartner, P.O., L. O'Dogherty, S. Goričan, E. Urquhart, A. Pillevuit, P.D. De Wever 1995: Middle Jurassic to Lower Cretaceous Radiolaria of Tethys: Occurrences, Systematics, Biochronology. – Mém. Géol., Lausanne, 23, pp. 1–1162.

Bérczinė Makk, A. 1999: Bükkzsérci (Észak-Magyarország) jura rétegsorok sztratigráfiai eredményei foraminiferák alapján. (Foraminiferal stratigraphy of Jurassic beds in Bükkzsérc [N-Hungary]). – Földt. Közl., 129, pp. 363–392.

Bérczinė Makk, A., P. Pelikán 1984: Jura képződmények a Bükk hegységből. (Jurassic formations from the Bükk Mountains). – Ann. Rep. Hung. Geol. Inst. 1982., pp. 137–166.

Bérczi-Makk, A., I. Fiedel-Matyók, P. Pelikán 1989: C-4. Bükkzsérc, Patkó cliff quarry. – XXIst European Micropalaeontological Colloquium (EMC), 4–13. 09. 1989 Hungary, Guidebook, pp. 156–160.

Bucković, D., B.C. Tešović, I. Gušić 2004: Late Jurassic paleoenvironmental evolution of the Western Dinarides (Croatia). – Geol. Carp. 55/1, pp. 3–18.

Clerc, C. 2005: Les Miliolina (Foraminifères porcelanés) du Dogger du Jura méridional (France): Systématique, stratigraphie et paléoenvoronnement. – Terre and Environnement, Univ. Genève, Thèse No. 3599, 250p.

Csontos, L. 1988: Étude géologique d'une portion des Carpathes Internes: le massif du Bükk (Stratigraphie, structures, métamorphisme et géodinamique). – Thése de doctorat, Univ. Sci. Techn. Lille Flandres-Artois, 250, Lille, 327 p.

Csontos, L. 1999: A Bükk hegység szerkezetének főbb vonásai [Structural outline of the Bükk Mts (N Hungary)]. – Földt. Közl., 129/4, pp. 611–651.

Csontos, L. 2000: A Bükk hegység mezozoos rétagtani újraértékelése.[(Stratigraphic reevoluation of the Bükk Mts (Hungary)]. – Földt. Közl., 130/1, pp. 95–131.

Csontos L., A. Bérczinė Makk, F. Thiebault 1991a: Újabb Foraminifera-leletek a Déli-Bükkből (New Foraminifer fossils from the Southern Bükk Mts). – MÁFI Évi Jel. 1989, pp. 383–410.

Csontos, L., L. Dosztály, P. Pelikán 1991b: Radioláriák a Bükk-hegységből (Radiolarians from the Bükk Mts). – MÁFI Évi Jel. 1989, pp. 357–382.

Csontos, L., A. Nagymarosy, F. Horváth, M. Kovác 1992: Tertiary evolution of the Intra-Carpathian area: a model. – Tectonophysics 208, pp. 221–241, Amsterdam.

Csontos, L., A. Vörös 2004: Mesozoic plate tectonic reconstruction of the Carpathian region. – Palaeogeogr., Palaeoclim., Palaeocol., 210, pp. 1–56.

Derin, B., Z. Reiss 1965: Note on some Jurassic and Early Cretaceous Trocholina (Foraminiferida) from Israel. – Oil Co. Micropal. Lab., report No. OS/1/65, 11 p, Jerusalem.

Dimitrijević, M.N., M.D. Dimitrijević, S. Karamata, M. Sudar, N. Gerzina, S. Kovács, L. Dosztály, Z. Gulácsi, Gy. Less, P. Pelikán 2003: Olistrotrome/mélanges – an overview of the problems and preliminary comparison of such formations in Yugoslavia and NE Hungary. – Slovak Geol. Mag., 9, pp. 3–21.

Dosztály, L. 1997: Észak-magyarországi mezozoós radiolária vizsgálatok (Investigations of Mesozoic Radiolarians from Northern Hungary). – Manuscript, MÁFI Archive.

Dosztály L., S. Józsa 1992: Geochronological evaluation of Mesozoic formations of Darnó Hill at Recsk on the basis of radiolarians and K-Ar age data. – Acta Geol. Hung., 35, pp. 371–393.

Dosztály L., Z. Gulácsi, S. Kovács 1998: Az észak-magyarországi jura képződmények rétegtana (Stratigraphy of the Jurassic formations in Northern Hungary). – In: Magyarország geológiai képződményeinek rétegtana (Stratigraphy of the geological formations of Hungary). MOL Rt – MÁFI, Budapest, pp. 309–318.

Dosztály, L., S. Józsa, S. Kovács, Gy. Less, P. Pelikán, Cs. Péró 2002: North-East Hungary. – In: Vozár J., R. Vojtko, L. Sliva (Eds): Guide to Geological Excursions, XVIIth Congress of the Carpathian-Balkan Geological Association, pp. 104–117. Bratislava.

Dozet, S., L. Šribar 1998: Biostratigraphy of shallow marine Jurassic beds in southeastern Slovenia. – Geologija, 40, pp. 187–221.

Dragastan O., S. Golubić, D.K. Richter 1996: Rivularia haematites: a case of the recent versus fossil morphology. Taxonomical considerations. – Rev. Españ. Micropal., 28, pp. 43–73.

Dragičević, I., I. Velić 2002: The northeastern margin of the Adriatic Carbonate Platform. – Geol. Croatica, 55/2, pp. 185–232.
Filipović I., D. Jovanović, M. Sudar, P. Pelikán, S. Kovács, Gy. Less, K. Hips 2003: Comparison of the Variscan – Early Alpine evolution of the Jadar Block (NW Serbia) and "Bükkium" (NE Hungary) terranes; some paleogeographic implications. – Slovak Geol. Mag., 9/1, pp. 3–21.
Flügel, E. 1982: Microfacies analysis of limestones. – Springer-Verlag, 633 p., Berlin, Heidelberg, New York.
Földessy, J-né 1975: A recski mélyszinti alaphegységi üledékes képződmények (Deep-seated sedimentary rocks of the basement at Recsk). – Földt. Közl., 105, pp. 598–611.
Galácz, A., A. Vörös 1972: A bakony-hegységi jura fejlődéstörténeti vázlata a főbb üledékföldtani jelenségek kiértékelése alapján (Jurassic history of the Bakony Mountains and interpretation of principal lithological phenomena). – Földt. Közl., 102/2, pp. 122–135.
Haas, J., S. Kovács 2001: The Dinaridic–Alpine connection – as seen from Hungary. – Acta Geol. Hung., 44/2–3, pp. 345–362.
Halamic, J., Š. Goričan 1995: Triassic and Jurassic radiolarites from the Mts Medvednica and Kalnik. – Geol. Croatica, 48/2, pp. 129–146.
Halamić, J., V. Marchig, Š. Goričan 2005: Jurassic radiolarian cherts in north-western Croatia: geochemistry, material provenance and depositional environment. – Geol. Carp., 56/2, pp. 123–136.
Henson, F.R.S. 1948: Foraminifera of the Genus Trocholina in the Middle East. – Ann. Mag. Nat. Hist., ser. 11, vol. 14, pp. 445–459.
Jenkyns, H.C. 1971: Speculation on genesis of crinoidal limestones in the Tethyan Jurassic. – Geol. Rundsch., 60/2, pp. 471–488.
Kozur, H. 1984: New radiolarian taxa from the Triassic and Jurassic. Geologisch – Palaeontologische Mitteilungen Innsbruck, 13/2, pp 49–88.
Leinfelder R.R., F. Schlagintweit, W. Werner, O. Ebli, M. Nose, D.U. Schmid, G.W. Hughes 2005: Significance of stromatoporoids in Jurassic reefs and carbonate platforms-concepts and implications. – Facies, 51/1–4, pp. 288–326.
Neagu, T. 1994: Early Cretaceous Trocholina group and some related genera from Romania. Part I. – Rev. Españ. Micropaleont., 26, pp. 117–143.
Neagu, T. 1995: The Cretaceous Trocholina group and some related genera from Romania. Part II. – Rev. Españ. Micropaleont., 27, pp. 5–40.
Pelikán, P., L. Dosztály 2000: Jurassic formations of the Bükkzsérc boreholes (SW Bükk Mts, NE Hungary) and their structural setting. – Földt. Közl., 130/1, pp. 25–46.
Pamić, J. 1997: The northwesternmost outcrops of the Dinaridic ophiolites: a case study of Mt. Kalnik (North Croatia). – Acta Geol. Hung., 40/1, pp. 37–56.
Pamić, J. 2003: The allochthonous fragments of the Internal Dinaridic units in the western part of the South Pannonian Basin. – Acta Geol. Hung., 46/1, pp. 41–62.
Pamić, J., S. Kovács, J. Vozár 2002: The Internal Dinaridic fragments into the collage of the South Pannonian Basin. – Geol. Carpath. 53, spec. issue. pp. 9–11.
Pentecost, A. 1991: Calcification process in algae and cyanobacteria. – In: Riding, R. (Ed.): Calcareous Algae and Stromatolites, pp. 3–20. Springer-Verlag, Berlin.
Pia, J. 1927: Thallophyta. – In: Hirmer, M. (Ed.): Handbuch der Paläobotanik 1, pp. 31–136, Oldenbourg, München-Berlin.
Portman, C., J.E. Andrews, P.J. Rowe, M.R. Leeder, J. Hoogewerff 2005: Submarine-spring controlled calcification and growth of large Rivularia bioherms, Late Pleistocene (MIS 5e), Gulf of Corinth, Greece. – Sedimentology, 25, pp. 441–465.
Protić, L., I. Filipović, P. Pelikán, D. Jovanović, S. Kovács, M. Sudar, K. Hips, Gy. Less, R. Cvijić 2000: Correlation of the Carboniferous, Permian and Triassic sequences of the Jadar Block, Sana-Una and "Bükkium" Terranes. – In: Karamata, S., S. Janković (Eds): Proceedings of the International Symposium Geology and Metallogeny of the Dinarides and Vardar Zone. Acad. Scien. Arts. Rep. Srpska, Collection and Monographs, 1, Dept. Nat., Mat. Techn. 1, pp. 61–69.

Radoičić, R. 1966: Microfacies du Jurassique des Dinarides externes de la Yugoslavie. – Geologija, 9, pp. 5–378.
Riding, R. 1992: Temporal variation in calcification in marine cyanobacteria. – J. Geol. Soc. London, 149, pp. 979–989.
Riding, R. 2000: Microbial carbonates: the geological record of calcified bacterial-algal mats and biofilms. – Sedimentology (Suppl. 1), 47, pp. 179–214.
Schlager, W. 2005: Carbonate sedimentology and sequence stratigraphy. – SEPM, 200 p.,Tulsa.
Schréter, Z. 1959 A Bükk-hegység tengeri eredetű permi képződményei (Permian fomations of marine origin in the Bükk Mts). – Földt. Közl., 89, pp. 364–373.
Septfontaine, M. 1978: Présence d'Archaeosepta platierensis Wernli 1970, dans le Jurassique briançonnais des Préalapes. Importance stratigraphique; relation avec le microfaciès et la paléogéographie. – Notes Lab. Paleontol.Univ. Genéve, no. 1, pp. 1–5.
Septfontaine, M. 1981: Les foraminifères imperforés des milieux de plate-forme au Mésozoique: détermination pratique, interprétation phylogénétique et utilisation biostratigraphique. – Rev. Micropaléont., 23, (3/4), pp. 169–203.
Tilšjar, J., I. Velić 1991: Carbonate facies and depositional environments of the Jurassic and Lower Cretaceous of the coastal Dinarides (Croatia). – Geol. Vjesnik, 44, pp. 215–234.
Tilšjar, J., I. Vlahović, I. Velić, B. Sokac 2002: Carbonate platform megafacies of the Jurassic and Cretaceous deposits of the Karst Dinarides. – Geol. Croatica, 55, pp. 139–170.
Turnšek, D. 1966: Upper Jurassic hydrozoan fauna from southern Slovenia. – Razpr. Pror. Med. Ved., Cl.4, 9, 8, pp. 337–428.
Turnšek, D., S., Buser, B. Ogorelec 1981: An Upper Jurassic reef complex from Slovenia, Yugoslavia. – SEPM Spec. Publ., 30, pp. 361–369.