GEOLOGICA CARPATHICA, APRIL 2008, 59, 2, 133–146

The red-algal facies of the Lower Badenian limestones of the Carpathian Foredeep in Moravia (Czech Republic)

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(Manuscript received January 27, 2007; accepted in revised form October 10, 2007)

Abstract: The existing data on Lower Badenian red-algal limestones from the Carpathian Foredeep in Moravia (Czech Republic), up to now dispersed in various publications and manuscripts, are summarized for the first time. They are discussed and interpreted according to contemporary carbonate sedimentology and actuopaleontology together with the latest results of field research and macro-/microscopic studies from 16 outcrops (Prace Hill, Židlochovice, Podbřežice, Bačov, Sudice, Pamětice, Sebranice, Světlá u Boskovic, Tišnov-Ochoz, Řepka, Lomnice, Olomouc, Hostim, Rebešovice, Blučina and Telnice). The Moravian red-algal limestones originated in a warm-temperate to subtropical climate and, in contrast to the Polish part of the Carpathian Foredeep, their areal extent and thickness are distinctly smaller due to the highly varied basin configuration. The predominating facies of red-algal limestones are biodetrital grainstones (fine-grained grainstones and bioclastic grainstones), coralline branch rudstones–floatstones and rhodolith rudstones. Red-algal limestones on the west and northwest margins of the preserved Carpathian Foredeep in Moravia are connected with the prograding coast line, and their positions in the profiles are not necessarily isochronous. At the eastern margin of the Carpathian Foredeep (immediately in front of the flysch nappes), important role of the redeposition of the red-algal limestones into more internal parts of the basin is supposed.

Key words: Middle Miocene, Lower Badenian, Carpathian Foredeep, Czech Republic, paleoecology, paleogeography, red-algal limestones.

Introduction

There are several aims of this paper: 1) to summarize for the first time the existing data on the Lower Badenian red-algal limestones from the Carpathian Foredeep (CF) in Moravia (Czech Republic), which so far are dispersed in various publications and manuscripts; 2) to discuss the latest own results of field research and macro-/microscopic studies from 16 outcrops (Prace Hill, Židlochovice, Podbřežice, Bačov, Sudice, Pamětice, Sebranice, Světlá u Boskovic, Tišnov-Ochoz, Řepka, Lomnice, Olomouc, Hostim, Rebešovice, Blučina and Telnice); 3) to evaluate the obtained data according to contemporary carbonate sedimentology and actuopaleontology and to use them for paleogeographical interpretations of the CF in the Early Badenian.

Geological overview

The Lower Badenian deposits of the Carpathian Foredeep (CF) in Moravia (Czech Republic) represent a final stage of the depositional history of the outer peripheral basins in the NW of the Central Paratethys. In Middle and South Moravia, its sediments overlie various blocks of the Bohemian Massif in front of the flysch nappes. In North Moravia, Silesia and Poland, they were partially overthrust by nappes formed during the late Styrian orogenic phase. The Lower Badenian is represented by the basal and marginal psammites and psephites, unstratified calcareous clays ("Tegel"), red-algal limestones (RAL) and exceptionally also biohermal bryozoan limestones. The present-day positions of these sediments represent only denudation relics of the original sedimentary cover, more complete ones in the E, markedly reduced ones in the W, with different postsedimentary tectonic histories of the various basin parts and even insufficiently detailed correlations of the individual Lower Badenian levels (Fig. 1). Formal lithostratigraphic units have still not been defined in the Badenian of the CF in Moravia.

RAL (formerly also "Leitha-", "lithothamnian" or "algal" limestones) are a bio- and lithofacially complicated complex of rocks forming blocks or lenses in calcareous clays with *Praeorbulina glomerosa* and *Orbulina suturalis* (nannoplankton Zone NN5 — Fig. 1), that represent the younger part of the Lower Badenian sedimentary cycle (Rögl et al. 2002). They are geographically situated between Hostim and Židlochovice in the S and the Moravian Gateway in the N, or rather between Hostim and Kralice in the W and the fronts of the flysch nappes in the E. Only very rare occurrences of Lower Badenian RAL are documented in the northern part of the Moravian CF (e.g. borehole Kravaře OS-1, Cicha et al. 1985 — Fig. 2).

RAL mainly occur in surficial outcrops, over 50 of them being known so far from the Moravian part of the CF (Novák 1975; Jašková 1998, 2002; Zapletal 2004). In the area between Vyškov and Brno, RAL were also found in 10 deeper borehole profiles (Fig. 2). The majority of surficial outcrops are represented only by denudation relics forming isolated rocks or tapering benches, with

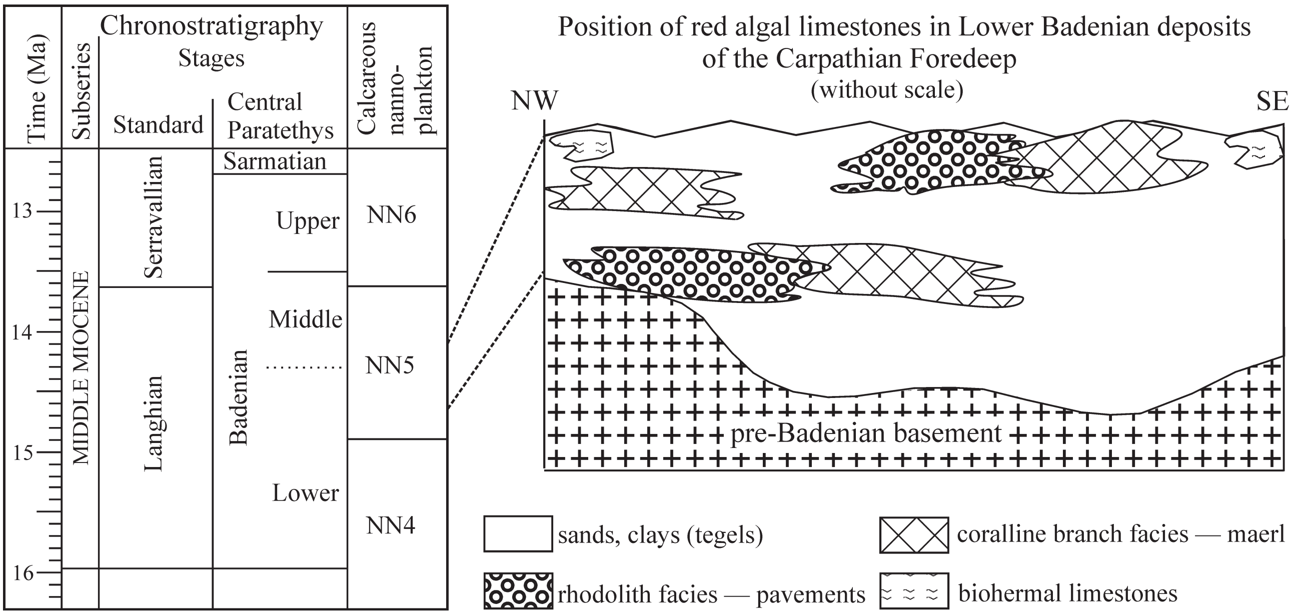

Fig. 1. Stratigraphic position of RAL in Lower Badenian deposits of the Carpathian Foredeep in Moravia (Czech Republic). Calibration according to Gradstein et al. (2004).

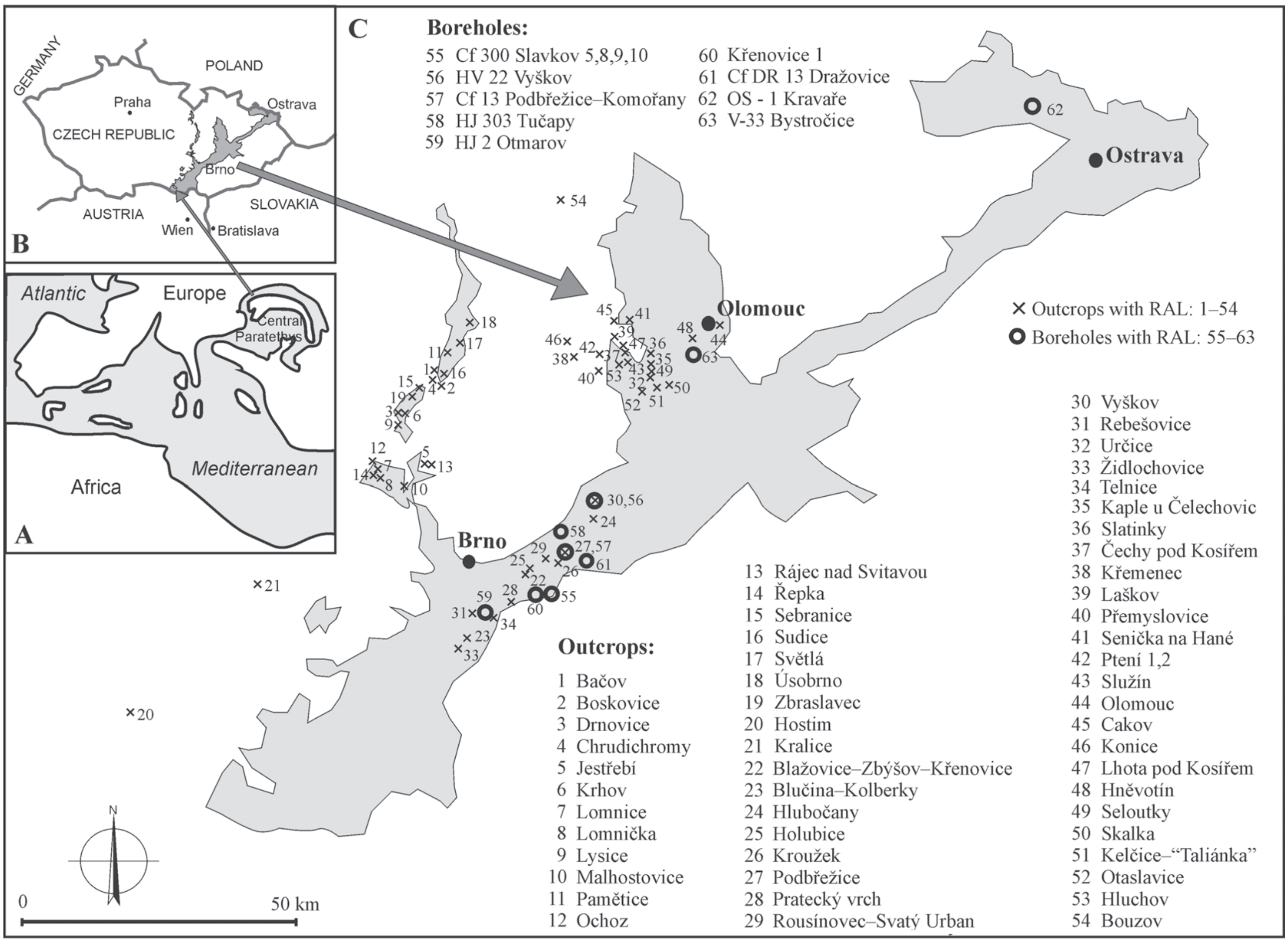

Fig. 2. Positions of the RAL outcrops and boreholes in the Carpathian Foredeep (CF). **A** — Paleogeography of the Central Paratethys in the Early Middle Miocene (Goncharova et al. 2004). **B** — Lower Badenian deposits in the CF. **C** — Outcrops and boreholes with RAL.

thicknesses not exceeding 1 m. Only 2 outcrops quarried in the past — Světlá u Boskovic and Prace Hill — can be taken as exceptions. At the locality Světlá u Boskovic the maximal thickness of RAL in the Moravian part of the CF (~44 m) has been verified by boreholes. The RAL of this locality form boulder-like disintegrating benches, mutually separated by layers of sands or calcareous clays and are overlain by calcareous clays (Novák 1975). Vaněk (fide Novák 1975) distinguished 3 RAL types at this locality with changing amounts of red algae, represented predominantly by branched forms with typical variable sizes of algal clasts, sharply changing even within one and the same layer. At the locality Prace Hill, the RAL — laterally as well as vertically passing into calcareous sandstones — alternate with parallel laminated sand beds in a 7 m thick profile (Fig. 4.1,3). The quarried material from this locality has also been used for the construction of the Peace Monument — the memorial to the battle near Slavkov/Austerlitz in 1805 (Fig. 4.2).

According to their positions within the Lower Badenian depositional succession, RAL are located directly upon the pre-Badenian basement, either within the calcareous clays or overlying them. RAL predominate within the calcareous clays. Only at the outer W and NW margins, they occur directly upon the pre-Badenian basement (and often with overlying pelites — Fig. 1). Overlying the calcareous clays, they can be found practically only in the outcrops east of Brno (Prace–Holubice–Kroužek–Židlochovice), often as isolated denudation relics. According to their relations to the pre-Badenian basement as well as to the calcareous clays, RAL were paleogeographically connected with transgression (e.g. Buday 1955; Hladíková et al. 1992) or regression (e.g. Cicha & Dornič 1960; Krystek & Tejkal 1968), prospectively with the shallowing of the sedimentary environment within the shallower neritic area (e.g. Novák 1975) in a subtropical climate. Only some outcrops of RAL were analysed in detail from the paleontological point of view (molluscs, foraminifers, red algae etc.; e.g. Kralice nad Oslavou — Procházka 1893, Hamršmíd 1984; Prace Hill, Židlochovice — Zdražílková 1988, Budíková 2003; Bačov, Sudice, Pamětice, Sebranice, Světlá u Boskovic, Tišnov-Ochoz, Řepka — Zdražílková 1988; Lomnice — Hudec 1986, Zdražílková 1988; Hostim — Hladíková et al. 1992; Rebešovice, Blučina, Telnice — Budíková 2003; Olomouc — Zapletal et al. 2001; Bouzov — Panoš et al. 1998; Služín — Vysloužil 1981; Slatinky — Kupková 1995). Hladil (1976), Hladil in Cicha (1978) and Hladil in Brzobohatý & Cicha (1978) processed coral fauna from RAL and calcareous clays. These data are often accessible in manuscripts only.

In situ biohermal bryozoan limestones were described only near Podbřežice in the E and Pamětice in the W (Figs. 2 and 3.1). Their interpretation at Podbřežice includes depth fluctuations within the shallow water environment and water temperature changes. At this locality red algae are almost missing in the lower part of the bioherm body and gain significance only in its upper part (Zdražílková 1988; Zágoršek & Holcová 2005).

In the following text the data on the Lower Badenian RAL from the CF in Moravia are summarized for the first time significantly specifying the paleogeographical interpretations of the CF in the above mentioned time span.

Methods of study

In the last years our own research was aimed at areally significant or newly uncovered RAL outcrops (field research, macro- and microscopic studies — ca. 80 thin sections): Prace Hill, Židlochovice, Podbřežice, Bačov, Sudice, Pamětice, Sebranice, Světlá u Boskovic, Tišnov-Ochoz, Řepka, Lomnice, Olomouc, Hostim, Rebešovice, Blučina and Telnice. Data obtained in this way are discussed and interpreted according to contemporary carbonate sedimentology and actuopaleontology, and are compared with older paleogeographical studies in the CF (see also Doláková et al. 2005). The thin sections and other materials are stored at the Institute of Geological Sciences, Masaryk University, Brno (abbreviations GU in Figs. 6–8), and at the Moravian Museum, Brno (abbreviations MZM in Figs. 6 and 8), Czech Republic.

Results

The studied sediments are represented by RAL with a changing amount of siliciclastic elements (0–50%) passing either into calcareous sandstones lacking biogenic component or into completely unsorted facies with whole rhodoliths and a mixture of micrite, other organisms and small algal fragments matrix almost lacking lithoclasts. In some localities (particularly Prace Hill), clay galls with diameters of even several cm (Fig. 4.4), often mixed with rhodoliths (Fig. 5.1,2), frequently occurred.

The dominating fossils are nongeniculate red algae followed by foraminifers with calcareous and agglutinated tests. On some outcrops encrusting foraminifers of the genus *Miniacina* were relatively common among algal crusts in rhodoliths. Large foraminifers are present in almost all outcrops, *Amphistegina*, *Heterostegina*, and *Elphidium*, together with tubes of serpulid worms and bryozoans are occasionally abundant (Fig. 6), even predominating over algae at the locality Podbřežice and in some layers of the locality Prace Hill (Fig. 4.5).

Bivalves, gastropods and echinoderms are abundant (Figs. 5.2,3, 6.3); ostracods, shark teeth, teeth and scales of teleosts and brachiopods occur occasionally. Corals are relatively rare (Fig. 5.1B) — *Tarbellastraea* and *Heliastraea* occur exceptionally (Novák 1975; Hladil 1976) and geniculate red algae are very uncommon (only the outcrops in the Boskovice Furrow and Olomouc). Green algae are particularly rare; only a few (2–3) specimens were found.

According to the classification scheme of carbonate lithofacies (Carranante et al. 1988), the RAL in the Moravi-

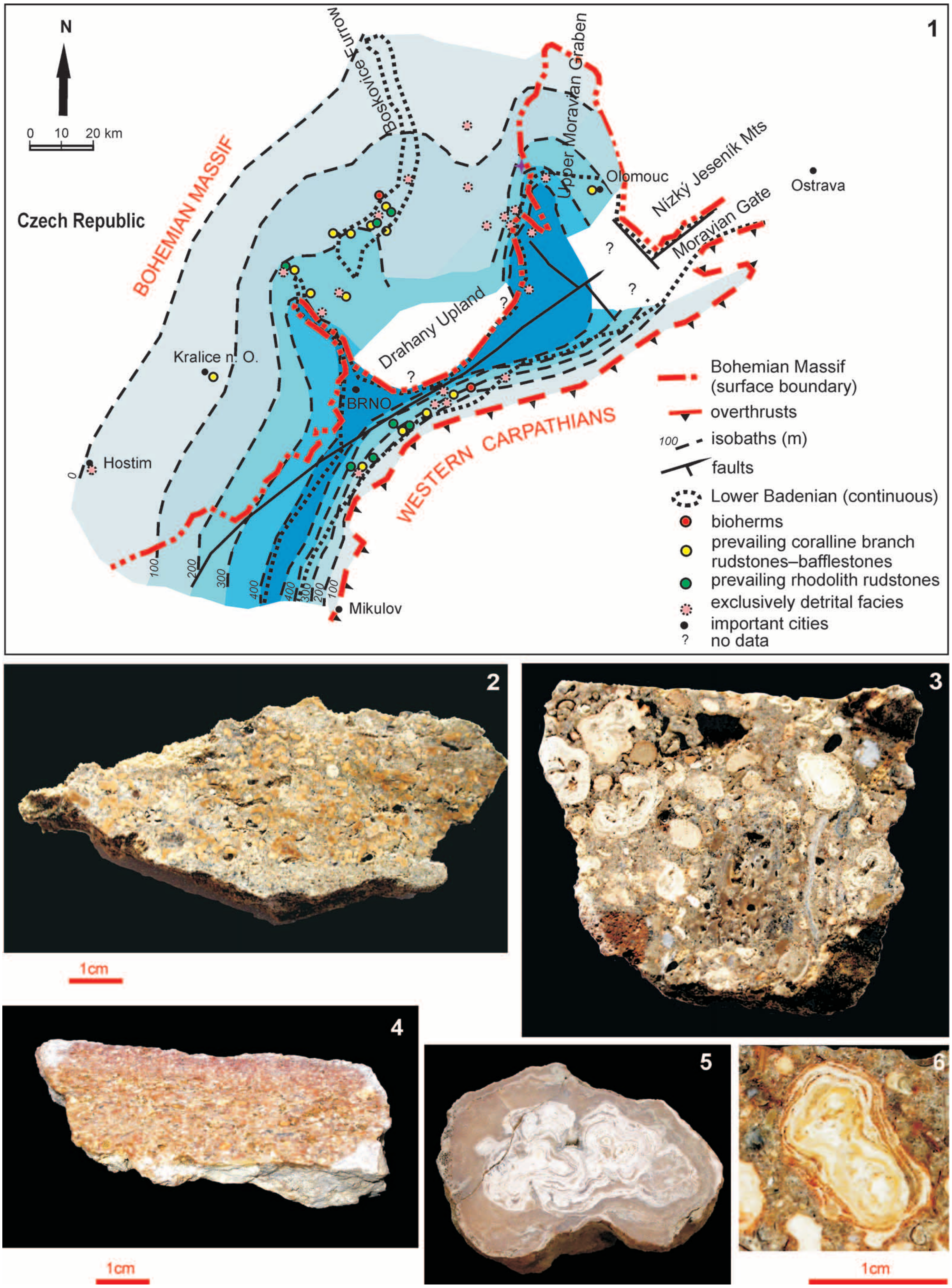

Fig. 3. RAL facies of the studied area. **1** — distribution of individual RAL facies and interpretation of the paleodepths of the Lower Badenian clays based on otoliths (Brzobohatý 2001); **2** — facies of coralline branch rudstones, Olomouc; **3** — facies of rhodolith rudstones, Prace Hill; **4** — facies of bioclastic grainstones (visible changes in grain size), Blučina; **5** — rhodolith — the algal bodies overgrown by bryozoan colonies, Židlochovice; **6** — binding of two adjacent rhodoliths, Prace Hill.

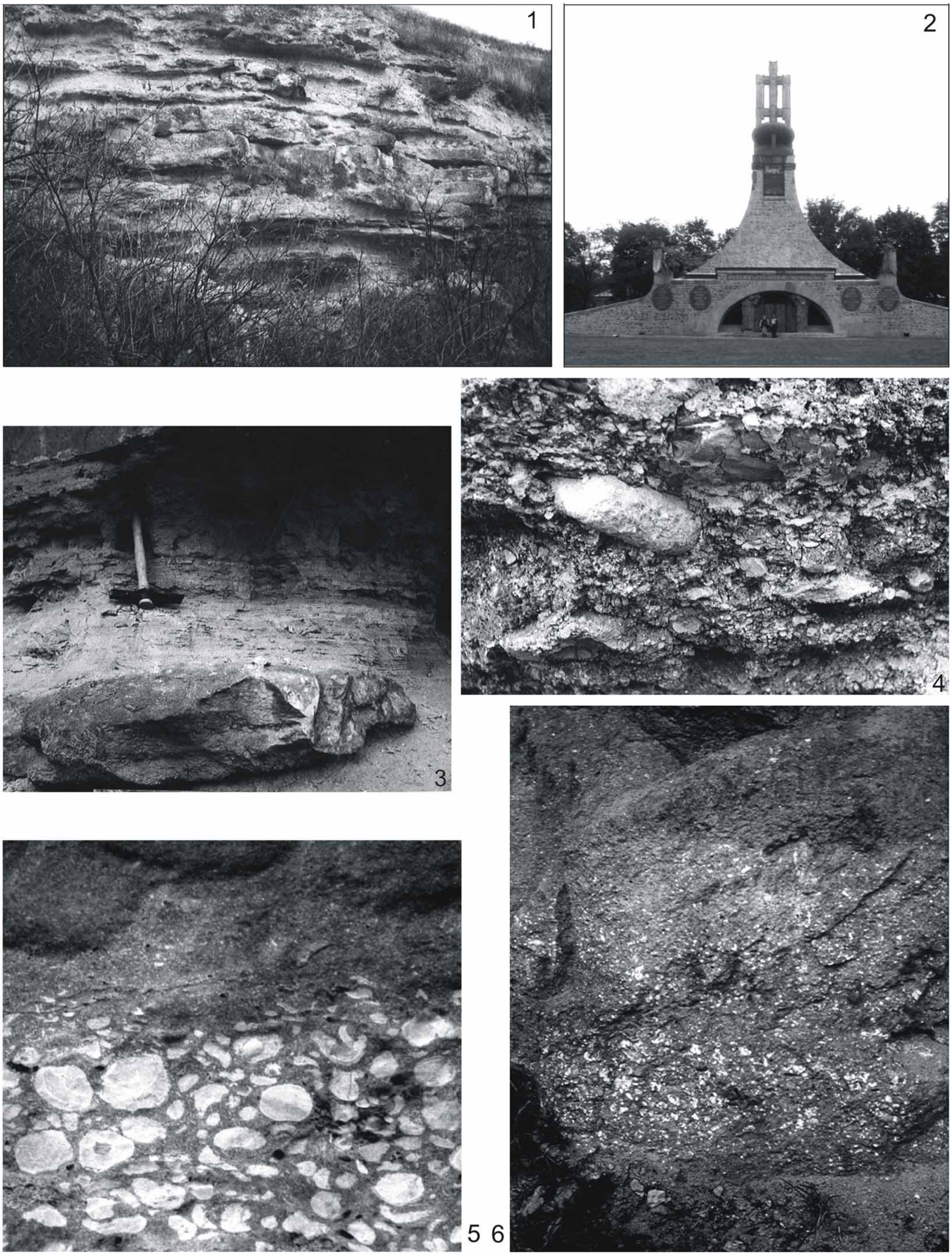

Fig. 4. Outcrops of Prace Hill: **1** — the wall of the former quarry — distinct banks of the RAL intercalated by sand layers; **2** — Peace Monument at the top of Prace Hill built of the RAL material from the former quarry; **3** — sand layer with horizontal lamination —quarry; **4** — the accumulation of clay galls — quarry; **5** — graded beds with bryozoans and red algae — Peace Monument; **6** — graded bed with rhodoliths — quarry.

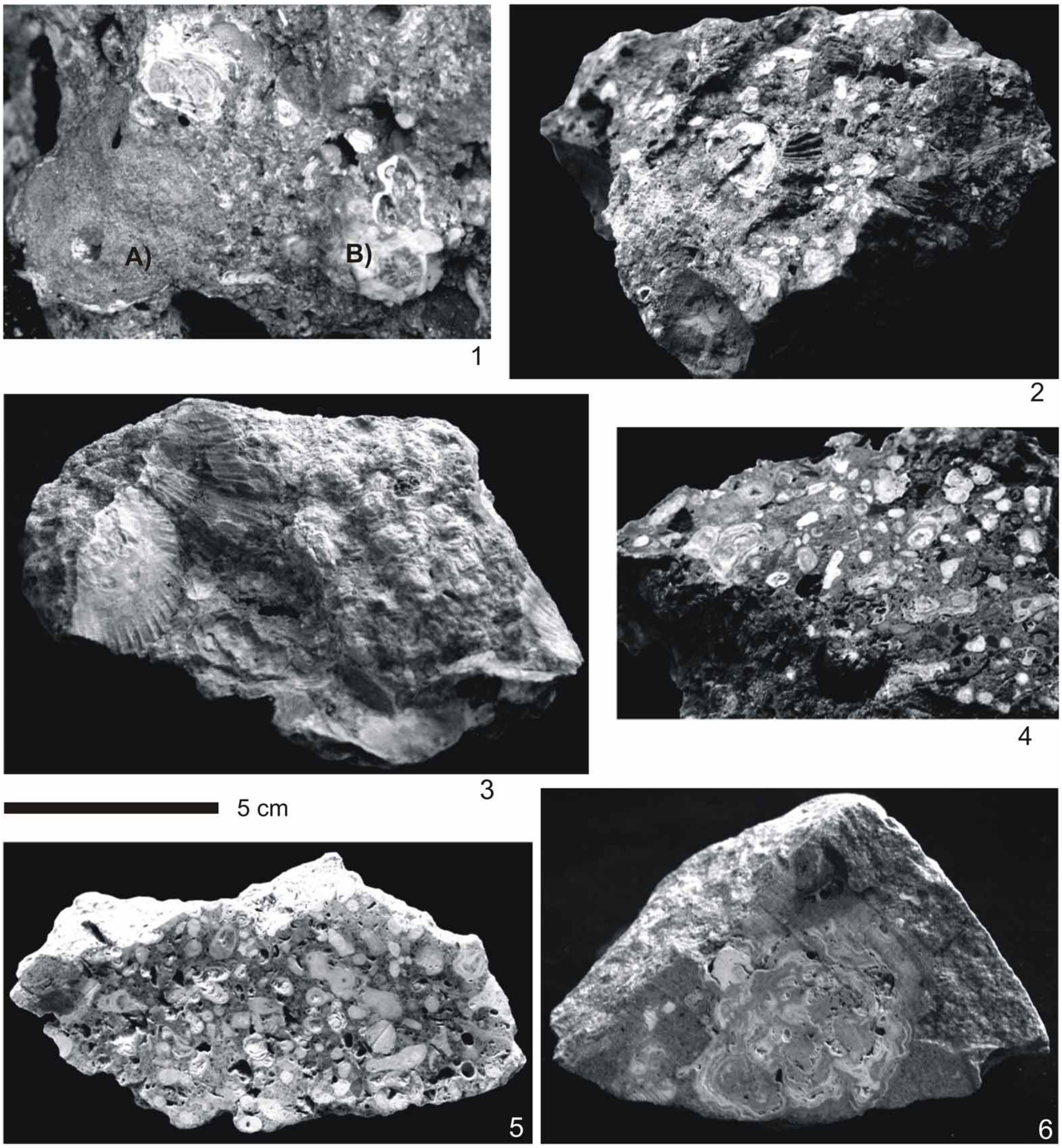

Fig. 5. The macroscopic image of RAL samples: **1** — rhodolith rudstones with great clay gall (A) and coral closed in rhodolith (B), Prace Hill; **2** — the same facies with molluscan fragments, Prace Hill; **3** — the pectinid shells with great rhodolith, Bačov; **4** — rhodolith rudstones with frequent binding, Prace Hill; **5** — coralline branch rudstones–floatstones, Pamětice; **6** — great symmetrical boxwork rhodolith, Židlochovice.

an part of the CF can be interpreted as rhodalgal facies dominated by red algae and bryozoans typical for subtropical to warm-temperate shelf conditions at the transition between the tropical zone (chlorozoan and chloralgal lithofacies) and colder or deeper temperate zone (molechfor lithofacies).

Warm-temperate to subtropical conditions are documented even in the results of palynological analyses from the surrounding Badenian calcareous clays. The palynospectra contained representatives of both thermophile (for example Sapotaceae, Palmae, *Engelhardia*) and deciduous arctotertiary floras (*Alnus*, Ulmaceae, *Carya*, *Juglans*). Palynological studies in the Židlochovice profile confirm MAT (mean annual temperature) of 15.70–19.40 °C on the coast of the basin (Bruch et al. 2004).

The predominating RAL facies are as follows:

1. Biodetrital grainstones — detrital facies with litho- as well as bioclasts that are reworked. These detrital facies differ mutually in their amount of siliciclastic material and size of bioclasts. Most of the bioclasts have micritized rims (Fig. 6.1). Two subtypes were documented:

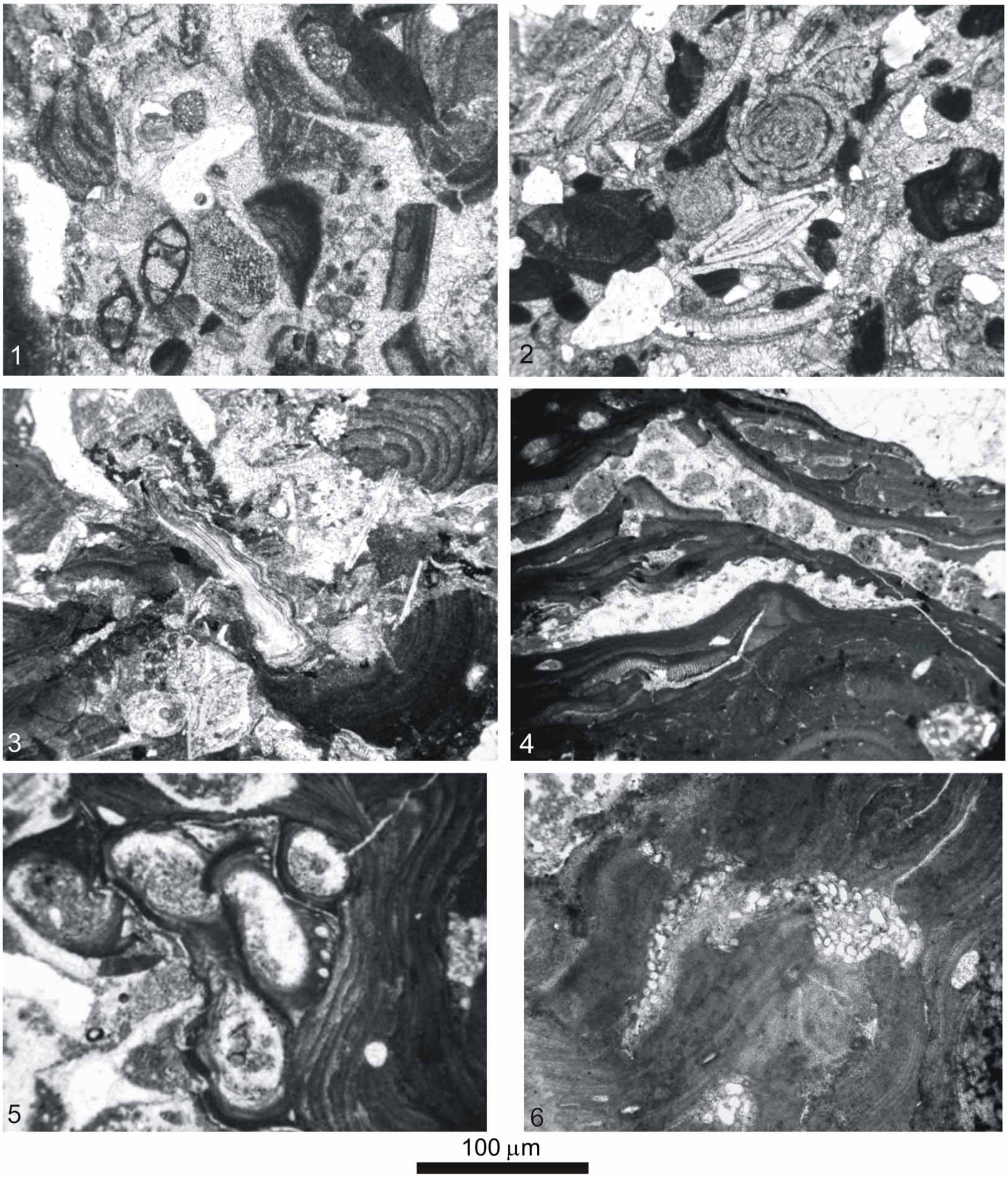

Fig. 6. Fossil organisms in RAL: **1** — bioclastic grainstones with textulariids (foraminifers), Bačov, GU RAL B24; **2** — *Amphistegina* sp. and *Borelis* sp., Světlá, MZM 21A; **3** — echinoid spines, fragment of brachiopod shell, foraminifers, Bačov, GU RAL B5; **4** — overgrowth of crustose red algae, bryozoans and sessile foraminifers in rhodolith, Prace Hill; **5** — colony of serpulid worms, Židlochovice, GU RAL Z17; **6** — sessile foraminifers among red-algal thalli, Lomnice, GU RAL L6.

a) fine-grained grainstones — litho- and bioclasts of approximately the same dimensions, well sorted, without micrite. Algal thalli are preserved only as very small undeterminable rounded fragments — unfragmented fossils are represented only by small foraminifers (Fig. 7.1);

b) packstones to bioclastic grainstones — larger fragments of bioclasts with or without lithoclasts, sometimes with micrite (Figs. 6.2,3, 7.2).

Occasionally rapid changes of average particle grainsize within a single layer can be observed (Fig. 3.1,2).

2. Coralline branch rudstones–floatstones with varying amounts of sparite and micritic groundmass, with bioclasts. Some of the samples lack siliciclastic lithoclasts. In the majority of outcrops fragments of branching forms prevail in thin sections (Figs. 3.2,4, 5.5, 7.3) but very frequently lesser amounts of rhodoliths and fragments of individual crusts can also be found (Fig. 7.4).

Rhodoliths of this facies comprise a low species diversity, they are exceptionally even monospecific, usually smaller, but massive, and include few bioclasts. They display very low primary porosities and lack the matrix among the crusts, for example, in the outcrops of Lomnice (Fig. 7.4) or Olomouc. Only very sporadic encrusting foraminifers and bryozoans can be observed among the crusts.

According to the character of groundmass and algal bodies (composed of both fragmented and unfragmented algal branches and rhodoliths) with various amounts of siliciclastic grains these facies are considered, after Rasser (2000), and Rasser & Piller (2004), to have formed in hydrodynamically protected areas (or in the deeper areas out of wave current action), whereas the more detrital facies with sparitic cement probably originated in areas with higher energy.

In the present-day North Atlantic and the Mediterranean these sediments are called ‘Maerl’; they are known from the shallowest subtidal down to the lower limit of the photic zone (Rasser 2000).

3. Rhodolith rudstones with mostly sparitic cement containing bio- and lithoclasts. The studied rhodoliths have multispecific growth and the majority of them a “boxwork” internal structure (Basso 1998). The algal crusts often change with the bryozoan colonies and serpulid tubes and scarcely with the sessile encrusting foraminifers of *Miniacina* (Figs. 3.3,5, 5.6, 6.4,5,6, 7.5,6,7,8). The cavities between the thalli and borings of several organisms are often filled with sediment; the binding of two or more small adjacent algal nodules to the bigger rhodoliths can frequently be observed (Figs. 3.6, 6.2, 7.6). After actuopaleontological investigations in the Mediterranean, Southern Gulf of California and Eastern Australia (e.g. Seneš 1975; Basso 1998; Halfar et al. 2000; Lund et al. 2000), as well as after results from the Middle Miocene Polish Korytnica Basin (Pisera & Studencki 1989), these types of rhodoliths develop under conditions of mild water dynamics. After Basso (1998), the binding of small algal nodules to the bigger rhodoliths with abundant annelid tubes is typical for water depths of about 90 m or more.

The locality Prace Hill seems to be a peculiar case — the rhodoliths are either situated in the sediment irregularly mixing with clay galls or they form beds in the rock (Figs. 3.3, 4.6, 5.1,2,4). Sometimes rhodolith-size diminishes upwards forming graded bedding — see Fig. 4.6 (Zdražílková 1987). According to Brandano et al. (2005) or Braga et al. (2006), such a characteristic represents sediment accumulations transported downslope by gravity flows and reworked by bottom currents, and occurs, for example, on the toe of a carbonate ramp slope. In our case they can even signal tectonic movements immediately in front of the flysch nappes (uplift of the Slavkov-Těšín ridge, Stráník & Brzobohatý 2000).

Among the branching algae as well as among the rhodoliths of the coralline branch rudstones–floatstones and rhodolith rudstones (see facies ad 2), there were sometimes very small unsorted particles of biogenic material, predominantly also represented by red algae (Fig. 7.7). According to Flügel (2004), these growth forms manifest a restricted water energy.

From the systematic point of view, much of the red-algal thalli are represented only by fragments and they are undeterminable. In the determinable ones the Melobesioideae represented mainly by the genera *Mesophyllum* (Fig. 8.3) and *Lithothamnion* (Fig. 8.4) are dominant, accompanied by the genus *Sporolithon* (Fig. 8.5,6) present in low amounts in the majority of outcrops. Mastoporoideae with the predominance of the species *Spongites albanensis* (Fig. 8.2) and Lithophylloideae represented mainly by the species *Lithophyllum duplex* (Fig. 8.1) are somewhat less frequent, but they were found at almost all the localities. Geniculate red algae were recorded sporadically.

After Braga & Aguirre (2001, 2004), the floristic differentiation of the coralline algae from reef to the temperate carbonate lithofacies is best marked in shallow-water environments, where it can be recognized at the subfamily level. The melobesioids dominate in deep tropical and shallow to deep temperate environments, usually reaching depths of 110–120 m. Algal assemblages with *Lithothamnion* and *Mesophyllum* dominant and *Sporolithon* common are characteristic of deep platform environments in tropical/subtropical conditions. Mastoporoids (for example *Spongites*) dominate in shallow-waters (max. to 40–50 m) mainly from reef units, being scarce to completely absent in the assemblages from temperate units. Lithophylloids are the most common element of shallow temperate carbonates (*Lithophyllum* is most abundant in less than 45 m depths and is scarce to absent below 60 m, Lund et al. 2000).

On the basis of the above mentioned results, we can suppose the existence of several different environments for the origin of RAL in the Moravian part of the Carpathian Foredeep. The mixture of both lithofacies and various red-algal subfamilies at the majority of localities could probably confirm frequent redepositions from shallower into deeper parts of the basin. Further systematic studies including the re-descriptions as well as the precise analyses of the growth forms of the red-algae at individual localities will be necessary for more detailed interpretations.

Interpretations of depositional environment and sequence stratigraphy

The transition from the Early to Middle Miocene coincides with significant sea-level fall (Haq et al. 1988; Hardenbol et al. 1998) and changing tectonic regime in the Alpine-Carpathian realm (Kováč et al. 2004). Exten-

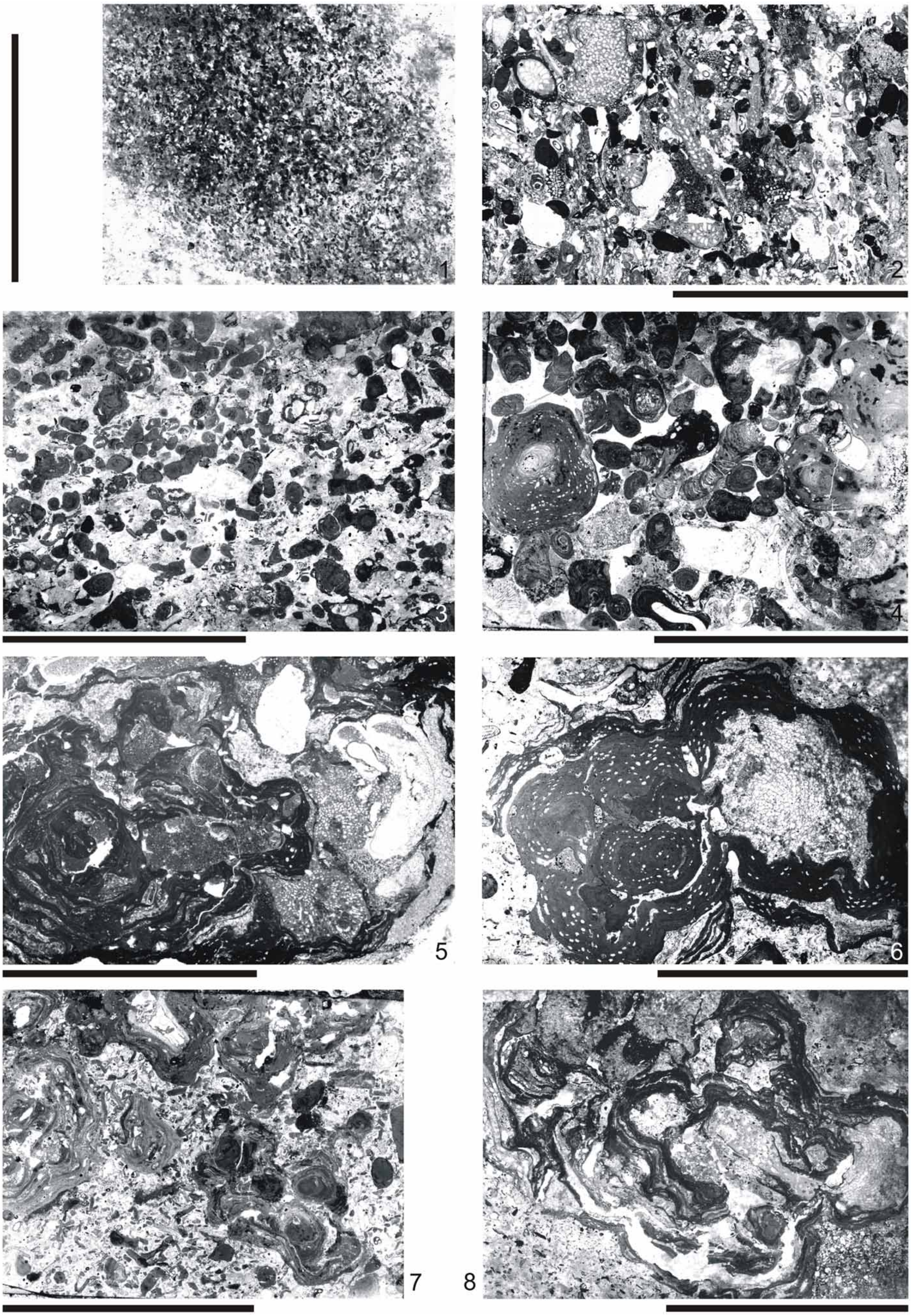

Fig. 7. RAL facies in thin sections. Biodetrital grainstones: **1**— fine-grained, highly sorted, without micrite, Řepka, GU RAL R9, 72949; **2** — with greater fragments of bioclasts, Blučina, GU RAL B15. Coralline branch rudstones: **3** — fragments of branched forms, Olomouc, GU RAL O3; **4** — prevailing branched forms with diffused small compact rhodoliths, Lomnice, GU RAL L2. Rhodolith rudstones: **5** — multispecific "boxwork" rhodolith with borings of several organisms, Židlochovice, GU RAL Z 18a; **6** — binding of two adjacent algal and bryozoan nodules to the bigger rhodolith, Prace Hill, GU RAL PV 2b; **7** — several fragmentary rhodoliths with groundmass lacking lithoclasts, Lomnice, GU RAL L7; **8** — multispecific "boxwork" rhodolith formed by thin crusts and big interspaces, penetrated by bryozoans and serpulids, Prace Hill, GU RAL PV 1. All scale bars are 2 cm.

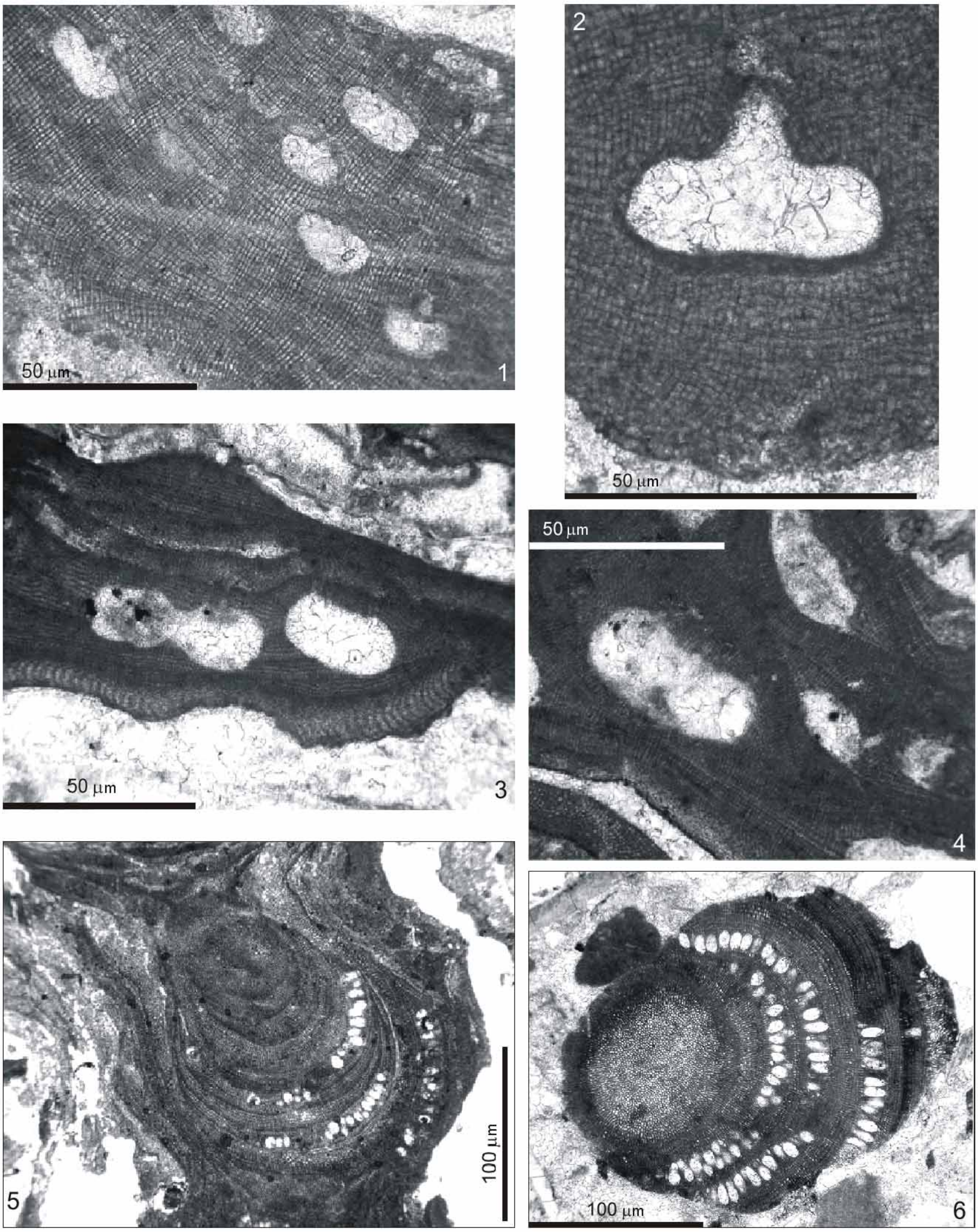

Fig. 8. Typical red algae from the studied thin sections. **1** — *Lithophyllum duplex* Maslov, Lomnice, GU RAL L2, ×100; **2** — *Spongites albanensis* (Lemoine) Braga, Bosence et Steneck, Prace Hill, GU RAL PV8, ×200; **3** — *Mesophyllum sancti-dionisii* Lemoine, Prace Hill, GU RAL PV1, ×100; **4** — *Lithothamnion* sp., Pamětice, GU RAL P28, ×100; **5** — *Sporolithon* sp., Lomnice, GU RAL L10, ×40; **6** — *Sporolithon* sp., Kroužek, MZM E16A, ×40.

sive marine transgression followed during the early Middle Miocene (the Early Badenian). All these factors directly influenced the evolution of basins in the foreland of the Alpine-Carpathian thrust wedge. Although the ruling factors of deposition and basin development are widely accepted for the broad area of the Central Paratethys (Kováč 2000), opinions about the development of Early to Middle Miocene sedimentary successions in the two adjacent foreland basins of the Carpathian Foredeep and the Alpine Molasse Zone remarkably differ. Numerous authors (Cicha

1995, 2001; Švábenická & Čtyroká 1998, 1999; Čtyroká & Švábenická 2000; Švábenická 2002; Rögl et al. 2002; Ćorić 2003; Ćorić & Rögl 2004; Ćorić & Švábenická 2004; Ćorić et al. 2004) published various statements about the evolution, biostratigraphy, and chronostratigraphic correlations of the individual sedimentary packages.

The 3rd-order depositional sequence was recognized within the Early Badenian sedimentary infill of the Carpathian Foredeep. Tectonic activity combined with eustatic sea-level change were the dominant ruling factors of basin formation and deposition during the Late Karpatian and Early Badenian (Nehyba & Šikula 2007). Compression of the Carpathian orogenic wedge oriented towards the NNW and NW changed its orientation towards NNE and NE during the Late Karpatian and Early Badenian (Kováč 2000). This shift led to the dominant formation of accommodation space (flexural subsidence) in the northern part of the CF whereas its south-western part (the studied one) was affected by relative uplift. Older basin infill (predominantly Karpatian in age) was eroded and deformed. A longitudinal depression along the basin axes (i.e. SW–NE direction — incised valley?) originated, followed by formation of coarse-grained Gilbert deltas along its margins (Nehyba 2006). Gravels, sandy gravels and gravelly sands (traditionally assigned as "marginal or basal clastics") are mostly interpreted as deposits of these deltas (Nehyba 2001). Such deposits are usually interpreted as lowstand and/or early-transgressive systems tract in the sequence stratigraphic models (Zaitlin et al. 1994; Emery & Myers 1996). Varied presence of tegel intraclasts within the deposits of coarse-grained Gilbert deltas (Nehyba et al. 2006) and description of deposits of Grund Formation in some parts of the foredeep (Cicha 1995, 2001; Ćorić & Rögl 2004) could be the evidence of a more complex position of these coarse-grained deposits. Stepwise flooding of the whole Pannonian Basin System during two Early Badenian transgressions is supposed by Kováč et al. (2007).

Flooding of the "entire" foreland basin is usually connected with the deposition of a thick pile of basinal pelites. They are traditionally assigned as "Tegel" and interpreted as shallow marine (shelf) to deep-water (bathyal) deposits (Brzobohatý 1989). This flooding was connected with eustatic sea-level change (TB 2.3 — sensu Haq 1991, CPC 3 — sensu Kováč 2000). Two Early Badenian transgressive phases of sea-level rise are traditionally supposed in the Carpathian Foredeep (Brzobohatý & Cicha 1993) with the second one probably more extensive. Lower Badenian basinal pelites can be tentatively interpreted as deposits of a transgressive systems tract. RAL are a part of this transgressive tract. Especially the RAL occurrences along the western margins of the CF suit this interpretation (Emery & Myers 1996). Nehyba et al. (in print) proposed subdivision of the "monotonous" pile of Early Badenian basinal pelites into segments with varied positions within the cycle of relative sea-level change (transgressive and high-stand systems tract?) and declared an important role of density currents for their deposition (hyperpycnites?, muddy turbidites).

Both detailed correlations of the Early Badenian sedimentary succession within the Carpathian Foredeep and their widely accepted lithostratigraphy are still missing. Inadequate biostratigraphical correlations also complicate the sequence stratigraphical model of the basin. Facies architecture of the varied segments of the basin infill based on correlations of preserved marginal and basinal facies can produce reliable sequence stratigraphy and lithostratigraphy for the Early Badenian deposits.

In the past, the RAL in the CF were interpreted as transgressive as well as regressive sediments, indicating subtropical climate and shallow-water sedimentary conditions (see Geological Overview). These interpretations were often incompatible with others concerning the surrounding pelites (lower sublittoral and upper bathyal), according to their foraminifers — Molčíková 1963, and otoliths — Brzobohatý 2001. The present state of the Lower Badenian research in the CF enables a somewhat different interpretation of the RAL.

In general, the studied RAL are situated in two paleogeographical positions, namely in the western parts of the CF, and in the central/eastern parts of the CF.

For the western margins of the CF, isolated relics of Lower Badenian deposits (Hostim, Kralice, Ptení…) are more typical than thick accumulations (Světlá). Their origin is connected with the Lower Badenian sea transgression onto the Bohemian Massif. Relative proximity of the basin margins can be supposed. Sandy beds occur below the RAL. For this area, the RAL facies of coralline branch rudstones–floatstones and fine-grained (well sorted) biodetrital grainstones are most typical. They generally reflect shallow depositional conditions. The RAL of this part of the CF can be interpreted as both in situ accumulations and erosional blocks redeposited into the basin. Relatively shallow conditions generally prevailed and intrabasinal paleoheights (relief) undoubtedly played an important role (the individual outcrops seem to partly form a "rim" along the Drahany Culm — see Figs. 2 and 3.1).

For the central and eastern parts of the CF, the fairly continuous preservation of the Lower Badenian deposits is typical. RAL occur within the mudstone deposits ("tegels" above and below RAL). In all the studied borehole profiles, the basal coarse-grained Lower Badenian deposits are absent or occur to a very limited extent; therefore it seems probable that RAL limestones are generally connected with places of limited coarse grained/sand input into the basin. The predominating RAL facies are biodetrital grainstones and rhodolith rudstones reflecting relatively deeper conditions. The absence of structures produced in the coastal environment within the clastic interbeds is typical. The sedimentary structures recognized in the associated clastic deposits (horizontal bedding, normal grading) as well as some structures within the RAL (presence of angular clasts, grading, poor sorting) clearly reveal the important role of sediment gravity currents (debris flows? — see angular blocks of RAL in the complex position at Holubice). These currents could be triggered by storms or tectonic activity along the active margin of the basin (Carpathian Flysch). This can explain the RAL positions within the mudstone beds as well as their variable positions within the Lower Badenian successions.

Discussion

The above mentioned interpretations even correspond to the latest conclusions for the Lower Badenian RAL of the Polish part of the CF where the sedimentation under temperate to subtropical conditions is supposed (Studencki 1999). Identical features of RAL in Moravia and in Poland primarily emphasize the systematic composition of the dominating groups — red algae, bryozoans, molluscs, worms, echinoids, great foraminifers — and the total absence of siliciclastic grains. The differences are represented by distinctly lower thicknesses and the extent of RAL in Moravia as well as by the total predominance of "organodetritic limestones" with a low proportion of in situ buildups. This can be caused by the more differentiated and bathymetrically deeper CF relief configuration in Moravia. The rather unique presence of green algae and sporadic but relatively more diversified hermatypic corals (4 genera, 7 species, only isolated specimens, no reefs — Hladil 1976) that are almost completely absent in Poland (Studencki 1999; Górka 2002) indicate the more southern position of the Moravian part of the CF and the somewhat warmer conditions. Thus they support the idea of a distinct climatically controlled N-S gradient in the Lower Badenian of the Central Paratethys documented in the decrease both of thermophile molluscs towards N (Harzhauser et al. 2003) and the gadoid cryophilic fishes towards S (Brzobohatý et al. 2007). These ascertainments even correspond to the existence of Lower Badenian coral reefs which were only documented in more southerly situated basins (northern Hungary, Styrian Basin, Bulgaria — Pisera 1996). Nevertheless, the RAL facies of the CF in Moravia do not exclude some temperature oscillations or temperature stratification of water. The isotopic studies of oxygen and carbon (foraminifers, molluscs and carbonate rocks) done at three outcrops from the Moravian part of the CF (so far published only from Hostim, Hladíková et al. 1992) obtained results revealing a wider spectrum of paleotemperatures, which could be caused not only by paleoclimatic conditions but also by various positions of studied localities within the basin. The interpretation of bryozoans in the profiles at Podbřežice also implies possible climatic oscillations with a cold period (Zágoršek & Holcová 2005).

Characters of RAL facies moderate or eliminate even the discrepancy with the paleobathymetry of the surrounding calcareous clays based on otoliths (Brzobohatý 2001). The RAL position inside the calcareous clays is not necessarily interpretable as a consequence of the bottom oscillations or the significant sea-level changes. The interbedding of the algal limestones with the clays could probably have been caused even by the redepositions of the rhodoliths and algal bioclasts in deeper parts of the basin (see above).

Only RAL from the western and north-western margins of the present occurrences of the Badenian sediments can be related to the Lower Badenian sea transgression in Moravia. Nevertheless, their deposition directly upon the pre-Badenian basement or in its very close proximity as well as the frequent presence of bathymetrically deeper overlying clays indicate that they are not connected with the maximum flooding surface (mfs), but with the prograding coastal line. The picture of RAL distribution on the present-day western border of the CF is a result of widespread erosion. This interpretation is confirmed, for example, by the litho- and biofacial analyses of the locality Hostim (Hladíková et al. 1992).

Conclusion

Biofacial and lithofacial analyses of the Lower Badenian RAL of the Moravian part of the Carpathian Foredeep confirm the sedimentary conditions of warm-temperate to subtropical climate. The sporadic presence of some groups (corals, green algae) indicates somewhat warmer waters than in the Polish part of the CF. This fact, together with the geographical position, documents a transitional position of the studied area between the northern margin of the Central Paratethys in Poland and the basins situated more southerly, and confirms the existence of a N-S oriented climatically dependent gradient with possible short-term temperature fluctuations in the Central Paratethys.

The areal extents and thicknesses of individual RAL occurrences in Moravia are distinctly smaller than in Poland. They are related to the very different conditions of basin configuration. The facies with predominating branched forms of red algae and with sporadic small compact rhodoliths probably originated in shallower waters (20–50 m according to the original assumptions). The facies dominated by rhodoliths with alveolar structures, bounded, with predominance of serpulids and Melobesioideae represent somewhat deeper environments. Sometimes distinct graded bedding in RAL occurrences on the eastern margin of the CF immediately in front of the flysch nappes (for example Prace Hill) gives evidence of downslope transport to greater depths caused by possible tectonic movements in this area.

The RAL occurrences on the western and north-western margins of the present shape of the basin can be connected with the prograding coast line, and so their positions in the profiles need not be isochronous. No connections of RAL with the regressive tendencies in the basin have been proved.

Acknowledgments: The authors express their sincere thanks to J.C. Braga (Granada), M.W. Rasser (Stuttgart), and an unknown rewiever for critical and constructive comments on the manuscript. The study was supported by the Research Project MSM0021622412 (Czech Republic).

References

Basso D. 1998: Deep rhodolith distribution in the Pontian Islands, Italy: a model for the paleoecology of a temperate sea. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 137, 173–187.

Brandano M., Vannuci G., Pomar L. & Obrador A. 2005: Rhodolith assemblages from the Tortonian carbonate ramp of Menorca (Spain): Environmental and paleoclimatic implications. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 226, 307–323.

Braga J.C. & Aguirre J. 2001: Coralline algal assemblages in upper Neogene reef and temperate carbonates in Southern Spain. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 175, 27–41.

Braga J.C. & Aguirre J. 2004: Coralline algae indicate Pleistocene evolution from deep, open platform to outer barrier reef environments in the northern Great Barrier Reef margin. *Coral Reefs* 23, 547–558.

Braga J.C., Martín J.M., Betzler Ch. & Aguirre J. 2006: Models of temperate carbonate deposition in Neogene basins in the SE Spain: a synthesis. In: Pedley H.M. & Carannante G. (Eds.): Cool-water carbonates: depositional systems and paleoenvironmental controls. *Geol. Soc., London* 255, 121–135.

Bruch A., Utescher T., Alcade Olivares C., Doláková N., Ivanov D. & Mosbrugger V. 2004: Middle and Late Miocene spatial temperature patterns and gradients in Europe — preliminary results based on paleobotanical climate reconstructions. *Cour. Forsch.-Inst. Senckenberg* 249, 15–27.

Brzobohatý R. 1989: A contribution to the paleogeography of the Lower Badenian Carpathian Foredeep in the area south-east of Brno. *Miscellanea micropalaentologica* IV, 133–141 (in Czech).

Brzobohatý R. 2001: Paleogeography, paleobiogeography and bathymetry on fish, particularly otoliths. *Ber. Inst. Geol. Paläont. K.-F.-Univ. Graz* 4, 37–40.

Brzobohatý R. & Cicha I. 1978: 4. Faziostratotypus: Borač. In: Papp A., Cicha I., Seneš J. & Steininger F. (Eds.): M4, Badenien (Moravien, Wielicien, Kosovien). Chronostratigraphie und Neostratotypen 6. *VEDA,* Bratislava, 171–173.

Brzobohatý R. & Cicha I. 1993: Carpathian Foredeep. In: Přichystal A., Obstová V. & Suk M. (Eds.): Geology of Moravia and Silesia. *MZM, PřF MU*, 123–128 (in Czech).

Brzobohatý R., Nolf D. & Kroupa O. 2007: Fish otoliths from the Middle Miocene of Kienberg at Mikulov, Czech Republic, Vienna Basin: their paleoenvironmental and paleogeographic significance. *Bull. Inst. Roy. Sci. Nat. Belgique*, *Sci. de la Terre* 77, 167–196.

Buday T. 1955: The contemporary state of stratigraphic research in the Lower and Middle Miocene of Lower Moravia. *Věst. Ústř. Úst. Geol*. 30, 4, 162–168 (in Czech).

Budíková M. 2003: Rhodophyta from selected outcrops of the Carpathian Foredeep. *MS*, *Diploma Thesis*, Masaryk University Brno (in Czech, English summary).

Carranante C., Esteban M., Milliman J.D. & Simone L. 1988: Carbonate lithofacies as paleolatitude indicators: problems and limitations. *Sed. Geol.* 60, 333–346.

Cicha I. 1978: 3. Faziostratotypus: Židlochovice. In: Papp A., Cicha I., Seneš J. & Steininger F. (Eds.): M4, Badenien (Moravien, Wielicien, Kosovien). Chronostratigraphie und Neostratotypen 6. *VEDA,* Bratislava, 168–170.

Cicha I. 1995: New information on the development of the Central Paratethys Neogene. New Results in Tertiary of the West Carpathians II. *Knihovnička ZPN* 16, 67–73 (in Czech).

Cicha I. 2001: Outline of the Middle Miocene stratigraphy in the Alpine-Carpathian Foredeep (Lower Austria, Moravia). *Scripta Fac. Sci. Nat. Univ. Masaryk. Brunensis*, 30, 23–26 (in Czech, English summary).

Cicha I. & Dornič J. 1960: Miocene development of the Boskovice Furrow between Tišnov and Ústí nad Orlicí. *Sbor. Ústř. Úst. Geol.* 26 (1959), *Odd. Geol*. 1, 393–434 (in Czech).

Cicha I., Brzobohatý R., Čtyroká J., Gabrielová N., Krejčí O., Krystek I., Mátl V., Molčíková V., Novotná E., Řeháková Z., Soták J., Staňková J., Knobloch E. & Váca F. 1985: Neogene in the OS-1 Kravaře and OS-2 Hať boreholes in the Opava basin. *Sbor. Geol. Věd*, *Geol.* 40, 183–229 (in Czech).

Ćorić S. 2003: Calcareous nannofossil biostratigraphy of the Mühlbach section (Gaindorf Formation, Early Badenian), Lower Austria. *Ann. Naturhist. Mus. Wien*. 104A, 15–21.

Ćorić S. & Rögl F. 2004: Roggendorf-1 borehole, a key-section for Early Badenian transgressions and the stratigraphic position of the Grund Formation (Molasse Basin, Lower Austria). *Geol. Carpathica* 55, 2, 165–178.

Ćorić S. & Švábenická L. 2004: Calcareous nannofossil biostratigraphy of the Grund Formation (Molasse Basin, Lower Austria). *Geol. Carpathica* 55, 2, 147–153.

Ćorić S., Harzhauser M., Hohenegger J., Mandić O., Pervesler P., Roetzel R., Rögl F., Scholger R., Spezzaferri S., Stingl K., Švábenická L., Zorn I. & Zuschin M. 2004: Stratigraphy and correlation of the Grund Formation in the Molasse Basin, northeastern Austria (Middle Miocene, Early Badenian). *Geol. Carpathica* 55, 2, 207–215.

Čtyroká J. & Švábenická L. 2000: Biostratigraphic evaluation of Badenian deposits on the Olomouc map-sheet (foraminifers and calcareous nannofossils). *Zpr. Geol. Výzk. v roce 1999*, 17–20 (in Czech with English abstract).

Doláková N., Brzobohatý R., Hladilová Š. & Nehyba S. 2005: Red-Algal Limestones and their relations to the palaeogeography of the Carpathian Foredeep — the present state of knowledge. In: 12th Congress R.C.M.N.S. 6–11. September 2005, Vienna, Patterns and Processes in the Neogene of the Mediterranean Region, Program, Abstracts, Participants. *University of Vienna, Department of Paleontology, Natural History Museum Vienna,* Wien, 66–68.

Emmery D. & Myers K.J. 1996: Sequence stratigraphy. *Blackwell Sci*., 1–297.

Flügel E. 2004: Microfacies of carbonate rocks. Analysis, interpretation and application. *Springer*, Berlin, Heidelberg, New York, 1–976.

Goncharova I.A., Shcherba I.G. & Khondkarian 2004: Map 5, Early Middle Miocene. In: Popov S.V., Rögl F., Rozanov A.Y., Steininger F.F., Shcherba I.G. & Kovac M. (Eds.): Lithological-paleogeographic maps of Paratethys, 10 maps Late Eocene to Pliocene. *Cour. Forsch.-Inst. Seckenberg* 250, 19–21.

Górka M. 2002: The Lower Badenian (Middle Miocene) coral patch reef at Grobie (southern slopes of the Holy Cross Mountains, Central Poland), its origin, development and demise. *Acta Geol. Pol.* 52, 4, 521–534.

Gradstein F.E., Ogg J.G., Smith A.G., Blecker W. & Louvens L.J. 2004: A new geologic time scale, with special reference to Precambrian and Neogene. *Episodes* 27, 2, 83–100.

Halfar J., Godinez-Orta L. & Ingle J.C. Jr. 2000: Microfacies analysis of recent carbonate environments in the southern Gulf of California, Mexico — a model for warm-temperate to subtropical carbonate formation. *Palaios* 15, 323–342.

Hamršmíd B. 1984: Contribution to the reconstruction of the sedimentary conditions of the Lower Badenian sediments in the Vicinity of Kralice nad Oslavou. *Zem. Plyn Nafta* 29, 1, 13–46 (in Czech, English summary).

Haq B.U., Hardenbol J. & Vail P.R. 1988: Mesozoic and Cenozoic chronostratigraphy and cycles of sea-level change. In: Wilgus C.K., Hastings B.S., Kendall C.G.S.C., Posamentier H.W., Ross C.A. & Van Wagoner J.C. (Eds.): Sea-level changes: An integrated approach. *SEPM (Society of Sedimentary Geology), Spec. Publ.* 42, 71–108.

Harzhauser M., Mandić O. & Zuschin M. 2003: Changes of Paratethyan marine molluscs at the Early/Middle Miocene transition: diversity, palaeogeography and palaeoclimate. *Acta Geol. Pol.* 53, 4, 323–339.

Hladil J. 1976: Badenian Scleractinia of the Carpathian Foredeep in Moravia. *MS, Diploma Thesis*, Masaryk University Brno (in Czech).

Hladíková J., Hladilová Š. & Nehyba S. 1992: Preliminary results of new investigations of Miocene sediments at Hostim (SW Moravia). In: Hamršmíd B. (Ed.): New results in Tertiary of the Western Carpathians. *Knih. Zem. Plyn Nafta* 15, 165–176.

Hudec P. 1986: Systematic and paleoecological analysis of Badenian molluscs from the locality Lomnice u Tišnova. *MS, Diploma Thesis*, Masaryk University Brno (in Czech).

Jašková V. 1998: Newly discovered Miocene outcrops in the surroundings of Prostějov. *Přírodovědné studie Muzea Prostějovska* 1, 133–139.

Jašková V. 2002: Revision of some algal limestone localities of the Carpathian Foredeep in the vicinity of Prostějov (Moravia). *Přírodovědné studie Muzea Prostějovska* 5, 99–101.

Kováč M. 2000: Geodynamical, paleogeografical and structural development of Carpathian-Pannonian region in Miocene: New perspective on Neogene basins of Slovakia. *VEDA*, Bratislava, 1–176 (in Slovak).

Kováč M., Andreyeva-Grigorovich A.S., Bajraktarevic Z., Brzobohatý R., Filipescu S., Fodor L., Harzhauser M., Nagymarosy A., Oszczypko N., Pavelic D., Rögl F., Saftic B., Sliva Ľ. & Studencka B. 2007: Badenian evolution of the Central Paratethys Sea: paleogeography, climate and eustatic sea-level changes. *Geol. Carpathica* 58, 6, 579–606.

Krystek I. & Tejkal J. 1968: Zur Lithologie und Stratigraphie des Miozäns im sw. Teile der Karpatischen Vortiefe in Mähren. *Folia Sci. Nat. Univ. Purkyn. Brun., Geologia* 9, 7, 1–31 (in Czech, German summary).

Kupková A. 1995: Biostratigraphic evaluation of the Badenian deposits from the Slatinky. *Čas. Slez. Muz. Opava* (A) 44, 1–12 (in Czech, English summary).

Lund M., Davies P.J. & Braga J.C. 2000: Coralline algal nodules of Fraser Island, Eastern Australia. *Facies* 42, 25–34.

Molčíková V. 1963: Processing of the Lower Tortonian microfauna of the Carpathian Foredeep. *MS Geofond*, Praha (in Czech).

Nehyba S. 2001: Lower Badenian coarse-grained deltas in the southern part of the Carpathian Foredeep (Czech Republic). *Abstracts of the 21 Meeting of IAS*, Davos, 96–97.

Nehyba S. 2006: Unusual depositional architecture of Foreland Basin deposits — a case study of Carpathian Foredeep Basin (Neogene). In: *Abstracts of the 17th International Sedimentological Congress, Vol. B*. Fukuoka, Japan. *International Ass. of Sedim.*, 221.

Nehyba S. & Šikula J. 2007: Depositional architecture, sequence stratigraphy and geodynamic development of the Carpathian Foredeep (Czech Republic). *Geol. Carpathica* 58, 1, 53–69.

Nehyba S., Petrová P. & Švábenická L. 2006: Intraclasts from Lower Badenian coarse-grained deposits — evidence of lost depositional environment (Carpathian Foredeep, Czech Republic). In: *Przebieg i zmienność sedymentacji w basenach przedgórskich. Instytut Geologii Podstawowej, Wydzial Geologii UW*, Warszawa, Polska, 144.

Nehyba S., Petrová P. & Zágoršek K. (in print): Sedimentological and palaeocological records of the evolution of the southern part of the Carpathian Foredeep (Czech Republic) during the Early Badenian. *Geol. Quart.*, Warszawa.

Novák Z. 1975: Lower Badenian limestones of the Carpathian Foredeep. *MS, PhD Thesis*, Brno (in Czech).

Panoš V., Novák Z., Pek I. & Zapletal J. 1998: Occurrence of the marine Lower Badenian from south of Bouzov. *Zpr. Geol. Výzk. v r. 1997*, 69–70 (in Czech).

Pisera A. 1996: Miocene reefs of the Paratethys: a review. Models for carbonate stratigraphy from Miocene Reef Complexes of Mediterranean Regions. *SEPM (Concepts in Sedimentology and Paleontology)* 5, 97–104.

Pisera A. & Studencki W. 1989: Middle Miocene rhodoliths from the Korytnica Basin (Southern Poland): environmental significance and paleontology. *Acta Palaeont. Pol.* 34, 3, 179–209.

Procházka V.J. 1893: Kralice Miocene at Náměšť in Moravia. *Věst. Král. Čes. Společ. Nauk, Tř. Math.-Přírodověd. (Praha)* 6, 1–71 (in Czech).

Rasser M.W. 2000: Coralline red-algal limestones of the Late Eocene Alpine Foreland Basin in Upper Austria: Component analysis, facies and paleoecology. *Facies* 42, 59–92.

Rasser M.W. & Piller W.E. 2004: Crustose algal frameworks from the Eocene Alpine Foreland. *Palaeogeogr. Palaeoclimatol. Paleoecol.* 206, 21–39.

Rögl F., Spezzaferri S. & Ćorić S. 2002: Micropaleontology and biostratigraphy of the Karpatian-Badenian transition (Early-Middle Miocene boundary) in Austria (Central Paratethys). *Cour. Forsch.-Inst. Senckenberg* 237, 47–67.

Seneš J. 1990: Some infra- and circalittoral ecosystems of the eastern part of the South Adriatic shelf. *Geol. Zbor. Geol. Carpath.* 41, 3, 199–228.

Stráník Z. & Brzobohatý R. 2000: Paleogeographic significance of the Upper Karpatian and Lower Badenian deposits along the eastern margin of the Carpathian Foredeep (South Moravia). *Slovak Geol. Mag.* 6, 2–3 (2000), 88–91.

Studencki W. 1999: Red-algal limestones in the Middle Miocene of the Carpathian Foredeep in Poland: facies variability and palaeoclimatic implications. *Geol. Quart.* 43, 4, 395–404.

Švábenická L. 2002: Calcareous nannofossils of the Upper Karpatian and Lower Badenian deposits in the Carpathian Foredeep, Moravia (Czech Republic). *Geol. Carpathica* 53, 3, 197–210.

Švábenická L. & Čtyroká J. 1998: Foraminifera and nannofossil biostratigraphic correlation of the Karpatian and Lower Badenian sediments in the Carpathian Foredeep of Moravia (preliminary results). *Zpr. Geol. Výzk. v roce 1997*, 166–169 (in Czech).

Švábenická L. & Čtyroká J. 1999: Biostratigraphic correlation (foraminifers and nannofossils) of the Karpatian and Lower Badenian sediments in the Alpine-Carpathian Foredeep (Moravia and Lower Austria). *Geol. Carpathica, Spec. Issue* 55, 79–80.

Vysloužil O. 1981: The Lower Badenian fauna from the locality Služín in the Carpathian Foredeep in Moravia. *MS, Diploma Thesis*, Masaryk University Brno (in Czech).

Zaitlin B.A., Dalrymple R.W. & Boyd R. 1994: The stratigraphic organization of incised valley systems associated with relative sea level change. In: Dalrymple R.W., Boyd R. & Zaitlin B.A. (Eds.): Incised valley systems: origin and sedimentary sequences. *SEPM, Spec. Publ.* 51, 203–210.

Zapletal J. 2004: Contribution to paleogeographic evolution of Lower Badenian sedimentation in central Moravia (Czech Republic). *Scripta Fac. Sci. Nat. Univ. Masaryk. Brun.* 31–32 (2001–2002), 87–98.

Zapletal J., Hladilová Š. & Doláková N. 2001: Marine sediments of the Lower Badenian marginal facies in Olomouc. *Scripta Fac. Sci. Nat. Univ. Masaryk. Brun.* 30 (2000), 75–82.

Zágoršek K. & Holcová K. 2005: A bryozoan and foraminifera association from the Miocene of Podbrezice, south Moravia (Czech Republic): an environmental study. In: Moyano G.H.I., Cancino J.M. & Wyse Jackson P.N. (Eds.): Bryozoan Studies 2004. *Taylor & Francis Group*, London, 383–396.

Zdražílková N. 1987: Preliminary report on paleontological investigations at Prace Hill. In: *3. pracovní seminář z paleoekologie. Katedra geologie a paleontologie PřF UJEP*, Brno, 101–106 (in Czech).

Zdražílková N. 1988: Corallinaceae in the lower Badenian of the Carpathian Foredeep. *Čas. Mineral. Geol.* 33, 2, 187–196 (in Czech, English summary).