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Stratigraphy and microfacies of the Jurassic and lowermost Cretaceous of the Veliky Kamenets section (Pieniny Klippen Belt, Carpathians, Western Ukraine)

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Key words: biostratigraphy, microfacies, ammonites, organic-walled dinoflagellates, calcareous dinoflagellates, calpionellids, Jurassic, lowermost Cretaceous, Pieniny Klippen Belt, Carpathians, Ukraine.

Abstract. The Veliky Kamenets section in the eastern part of the Pieniny Klippen Belt in the Ukrainian Carpathians shows a well exposed, 83 m thick succession composed of Jurassic and lowermost Cretaceous (Berriasian) deposits. The terrigenous part of the section includes: gravels with a sandy matrix (unit 1A), massive grey-green sandstones (unit 1B) and shales with intercalations of siltstones/sandstones and oyster/gastropod lumachelles (unit 2). Organic-walled dinoflagellates document the Toarcian-Aalenian age of the siliciclastic deposits of unit 2. The carbonate part of the succession embraces: stromatactis mud-mounds interfingering with crinoidal limestones (unit 3A), lower nodular limestones (unit 3B), cherty limestones (unit 3C), upper nodular limestones (unit 3D), pink pelitic limestones (unit 3E), limestones with a volcanogenic bed (unit 5) and limestone breccia limestones (unit 6). This succession has yielded abundant ammonites from the Bathonian, Oxfordian and Kimmeridgian (with a stratigraphical hiatus covering the Callovian and Lower Oxfordian), as well as calcareous dinoflagellates (from the Upper Oxfordian towards the top of the succession), and calpionellids (in the Tithonian and Berriasian). Detailed stratigraphical study of the succession based both on ammonites and microfossils has resulted in the recognition of biostratigraphical units and their correlation with the chronostratigraphical scale.The microfacies recognized in the pelagic part of the succession include: the "filament" (*Bositra*) microfacies (Bathonian), the planktonic foraminifer microfacies (Oxfordian), the *Saccocoma* microfacies (Kimmeridgian to Upper Tithonian), and the calpionellid microfacies (Upper Tithonian–Berriasian). The volcanogenic rocks (lava flows and volcanic ash) appear in the topmost part of the succession (units 4 to 6) and this volcanic event is very precisely located in the Elliptica-Simplex chrons of the Middle and Late Berriasian.

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INTRODUCTION

The Veliky Kamenets section at Novoselica Village (Fig. 1) is the key section of the Pieniny Klippen Belt of the Western (Transcarpathian) Ukraine. The section is exposed in a large, a long-active quarry (Fig. 2), where the massive Jurassic limestones, including especially those of the ammonitico-rosso type, have been exploited and polished. It was described previously by Matějka (1929) and Andrusov (1945) who recognized here the following stratigraphical units:

1. Yellow, soft sandstones of unknown age (possibly Lower or Middle Jurassic);
2. Grey and green-grey shales with intercalations of grey sandstones containing coal fragments, and of bivalve lumachelles, about 12 m in thickness (?Aalenian);
3. Pink crinoidal limestones containing manganese concretions at the base (Bathonian);
4. Nodular limestones of the Czorsztyn Limestone type (*i.e.* of the ammonitico-rosso type), about 15 m in thickness (Upper Jurassic);
5. Pink stylolitic limestones (Tithonian) with intercalations of crinoidal limestones at the top; these deposits are in contact with volcanics of the basic andesite type representing possibly both lava flows and tuff breccias.

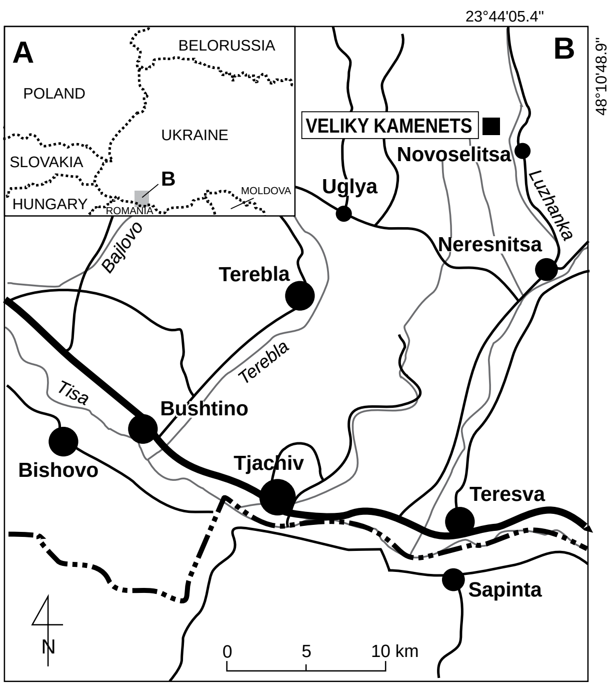


Fig. 1. Location maps showing the positions of the Veliky Kamenets section (B) and the region investigated (A)

The same section has also been described by Slavin (1963, 1966, 1972) who additionally recognized here limestones with cherts at the top of the nodular limestones.

The succession of deposits exposed in the Veliky Kamenets quarry has been distinguished by Slavin (1963, 1966, 1972) as representative of the so-called Kamenets facies zone which was formed over the hypothetical submarine swell surrounded to north and south by deep-water basins during the Jurassic and Early Cretaceous (the Tissalo facies zone and the Svalyava facies zone, respectively: see Slavin, 1966, figs 18–19). The Kamenets Succession constituted a fragment of the Pieniny Klippen Basin, an important part of the oceanic domain of the Ligurian-Penninic-Vahic-Transilvanian Ocean which existed in the northern part of Tethys during the Jurassic and Cretaceous (Golonka *et al.*, 2000). The Kamenets Succession could represent the eastern continuation of the Czorsztyn Succession deposited over the counterpart of the Czorsztyn Ridge (Swell), well recognized in Polish and Slovakian sections of the Pieniny Klippen Basin (Birkenmajer, 1963, 1977, 1986; Mišík, 1994).

The new data on the Kamenets section have been provided during the realization of a grant of the Polish State Committee for Scientific Research by a team of Polish, Slovakian and Ukrainian geologists during 2001–2004 (see Wierzbowski *et al.*, 2004). Of the published results having a wider general interest are those resulting from palaeomagnetic studies (Lewandowski *et al.*, 2005): these proved that during the Late Callovian – Early Oxfordian (a hiatus well indicated by ammonites; *cf.* also Rakús,1990), took place a marked palaeolatitudinal shift indicating a fast southerly movement of the Kamenets block. The shift has been interpreted as the result of fast opening of the oceanic domain (the Magura Ocean represented possibly by the Tissalo facies zone in the area of study) to the north of the Kamenets swell at the turn of the Middle and Late Jurassic. A similar shift has been confirmed subsequently in other sections of the Pieniny Klippen Belt both in Poland and Slovakia which indicated the wide palaeogeographical importance of the phenomenon distinguished as the Metis event (Lewandowski *et al.*, 2006; Matyja, Wierzbowski, 2006). Some sedimentological problems have been elaborated in detail also – such as the occurrence of stromatactis mud-mounds in the deposits of Bajocian to Bathonian age in the Veliky Kamenets section. These were interpreted together with similar mud-mounds known from the Jurassic in different parts of the Pieniny Klippen Belt as structures of organic origin (Aubrecht *et al.*, 2002, 2009). Nevertheless, the detailed knowledge of the section

Fig. 2. The Veliky Kamenets section (numbers of lithostratigraphic units are indicated)

The horizon related to a marked palaeolatitudinal shift of the Kamenets area (Metis event) is arrowed

in question (fossils, microfacies and stratigraphy) has until recently been poorly documented in published statements, being mostly limited to conference abstracts (*e.g.* Krobicki *et al.*, 2003; Reháková *et al.*, 2006).

For these reasons the present authors decided to undertake this study of the Veliky Kamenets section.

LITHOLOGY AND LITHOSTRATIGRAPHY

The following lithostratigraphic units have been distinguished in the section studied (Figs 2, 3, *cf.* also Krobicki *et al.*, 2003; Lewandowski *et al.*, 2005): light gravels with a sandy matrix (unit 1A); massive grey-green sandstones (unit 1B); black and grey shales with spherosiderites and intercalations of siltstones/sandstones and oyster/gastropod lumachelles (unit 2); Neresnitsa limestones (unit 3; see also below) subdivided into: red stromatactis mud-mounds with crinoidal limestones (unit 3A), red lower nodular limestones (unit 3B), brick-red cherty limestones (unit 3C), pale-red upper nodular limestones (unit 3D), pink massive pelitic limestones (unit 3E), black basaltic pillow lavas (unit 4), volcanic ash (5b) sandwiched between fossiliferous (5a) and pelitic (5c) limestones and breccia limestones (unit 6).

Unit 1A – gravels with sandy matrix ("pudding sandstones" of Kruglov, 1969)

The top part of the unit exposed is about 3 m in thickness, but the full thickness is not known. These are light, poorly cemented, and poorly sorted gravels with an abundant sandy quartz matrix; the gravels are composed mostly of white and pink quartz/quartzitic clasts. In thin sections a minor content of feldspar and mica was noted; the presence of kaolinite in the matrix has been recognized (Kruglov, 1969).

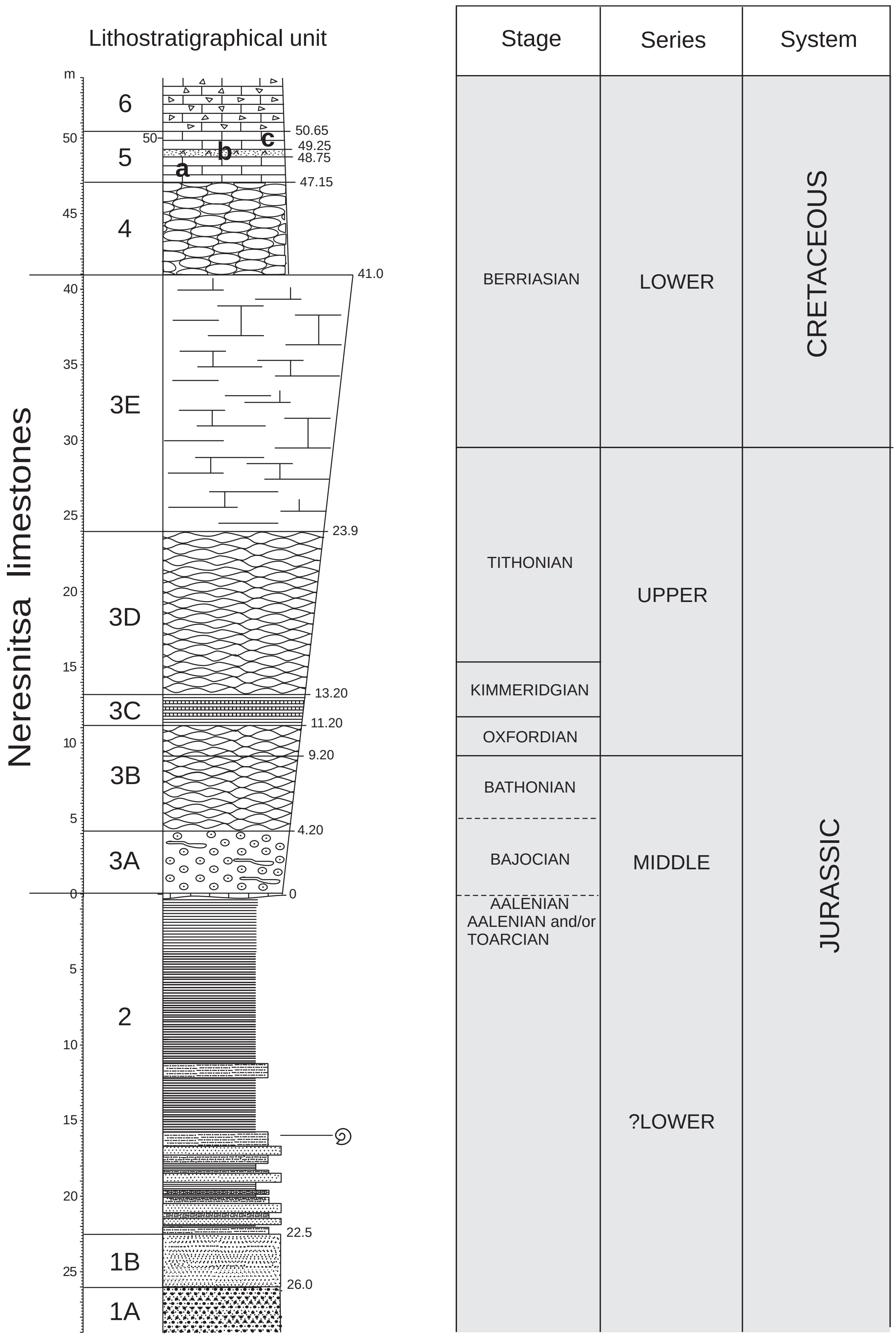


Fig. 3. The lithostratigraphic units in the Veliky Kamenets section and their chronostratigraphical interpretation

Lithologies are explained in the text

Unit 1B – massive grey-green sandstones

These are massive, grey-green, medium grained, poorly sorted sandstones which constitute a rock-unit about 3.5 m in thickness. Sparsely placed pebbles up to 3 cm in diameter are found. Some horizons are greenish and rich in glauconite. No fossils have been found.

Unit 2 – shales with intercalations of siltstones/sandstones and oyster/gastropod lumachelles

The following succession (from below) is recognized:

1. Siltstones to fine grained sandstones and shales; two levels with siderite occur – at 1.30 m from the base, and about 1 m below the top; plant-remains are especially common in the lower part of the unit which is more rich in fine-grained sandstones often showing ripple lamination. The ammonite *Zetoceras* sp. has been found in a thin oyster lumachelle at 15.9 m below the top of the unit 2 (Fig. 3). The subunit is 6.80 m in thickness.
2. Grey-green silty shales – 3.60 m in thickness.
3. Grey-green siltstones with muscovite and plant fragments – 0.90 m in thickness.
4. Black shales – 2.85 m in thickness.
5. Black shales with thin intercalations of marly limestones and siltstones (in the lower and middle part of the unit), and with a few layers of oyster and gastropod lumachelles in the upper part of the unit (about 5.50 thick). The intercalations of lumachelles attain 0.1–0.25 m in thickness. The top of the uppermost lumachelle bed is a discontinuity surface as shown by incrusting oysters. The subunit is 14.15 m in thickness.

Plant remains occur in the whole unit, being represented mostly by wood fragments and detritus, but sometimes also by laminae and lenticules of jet. The thickness of the unit is 22.35 m.

Unit 3 – Neresnitsa limestones

These embrace all the types of limestones building the summit of the Veliky Kamenets Mt (Fig. 2), which are exploited as the so-called “Neresnitsa marbles”. This term is the newly introduced, an informal term for all these deposits. They attain 41 m in thickness.

The deposits occurring directly above the mentioned discontinuity surface at the top of unit 2 are variegated in colour micritic, slaty limestones 0.3 m in thickness. The limestones are burrowed, and the burrows are filled with crinoid material.

Unit 3A – stromatactis mud-mounds interfingering with crinoidal limestones (between 0.3–4.2 m of the Neresnitsa limestone section – Fig. 3)

A marked discontinuity surface is developed at the contact of the slaty limestones and crinoidal limestones units. Directly above the surface, in the lowermost part of the crinoidal limestones, there occur ferrugineous concretions and ferrugineous crusts, clasts of cherry-green micritic limestones and yellow bivalve and serpulid lumachelles; some indeterminable ammonites and brachiopods with reversed geopetal structures have been also found here. Unit 3A can be divided in two parts. The lower part, 2.3 m in thickness, is dominated by crinoidal debris, but includes also many tabular stromatoporoids and several small, 0.2–0.5 m in thickness, stromatactis mud-mounds. The upper part of the unit 3A, 2.0 m in thickness, is dominated by stromatactic mud-mounds. Stromatoporoids are absent and crinoidal debris is less common in thin crinoidal intercalations.

These deposits are cut by another discontinuity surface coated with ferruginous crusts.

Unit 3B – lower nodular limestones (between 4.2–11.2 m of the Neresnitsa limestone section)

The lower boundary of the unit is a discontinuity surface at the top of unit 3A, and its upper boundary runs directly below the first, non-nodular, thin layer of unit 3C (Fig. 4).

Unit 3B is composed of two facies types: a stromatolitic facies and a nodular facies. The mud-mounds with stromatactis structures (Aubrecht *et al.*, 2002) are confined to the first facies type. A set of distinct discontinuity surfaces occurs within unit 3B, 5 meters above its lower boundary. These discontinuities represented by two or sometimes three sharp, irregular surfaces covered by Fe-Mn oxides occurring within a *ca*. 10 cm thick interval of red limestone. Thin sections show the “filament” (*Bositra*) microfacies below, and the planktonic foraminifer *Globuligerina* microfacies (Pl. 10: 1) above the lowest of these discontinuity surfaces (Fig. 7).

Unit 3C – cherty limestones (between 11.2–13.2 m of the Neresnitsa limestone section)

This unit markedly differs from underlying and overlying ones in the presence of well developed bedding. Two sets of thin-bedded (4–5 cm) limestones are present in the lower and upper parts of unit 3C. The middle part of the unit is represented by red marls with flat lenticulate cherts, sandwiched in between organodetrital limestones composed of large fragments of *Saccocoma*; the boundaries between the marls and limestones are not sharp.

The thin-bedded limestones (sample 14a) show the presence of biomicrite to biopelmicrosparite wackestone with planktonic foraminifers (*Globuligerina*), aptychi, ostracods, radiolarians, fragments of planktonic crinoids (*Saccocoma*), sponge spicules and benthic foraminifers. Directly above (sample 14b) there occurs pelbiomicrosparite limestone of the radiolarian microfacies. It contains calcified radiolarians, *Saccocoma*, ostracods, benthic foraminifers, and calcareous

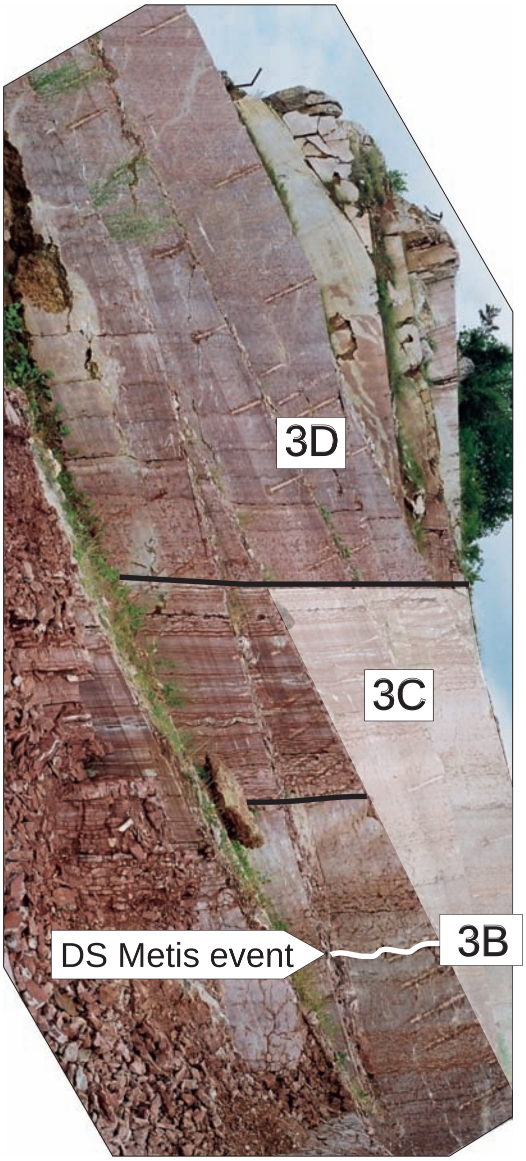


Fig. 4. Part of the section of the Neresnitsa limestones with units 3B to 3D

dinocysts. Packstones of the *Saccocoma* microfacies have been recognized in a thin section (sample 21) of thin-bedded limestone from the upper part of the unit. Less frequently there occur here radiolarians, aptychi, as well as rare small foraminifers and ostracods. Close to the top of the unit there occurs pelbiomicrosparite of the *Saccocoma* – cadosinid microfacies (sample 22, Pl. 10: 3) with frequent radiolarian tests (sample 22). The bulk of these „pellets“ are probably micrite infillings after the dissolved radiolarian tests. Deposits occuring in the middle part of the unit (samples 15–20), are represented by packstones and wackstones of the *Saccocoma* microfacies. The biofragments are partially silicified and are concentrated in laminae (Pl. 10: 2).

Unit 3D – upper nodular limestones (between 13.2–23.9 m of the Neresnitsa limestone section)

Unit 3D is composed of two facies types: nodular and stromatolitic ones.The well developed nodular limestones occur in the lowermost part of the unit, from its base up to about 0.75 m above. The limestones are of the *Saccocoma* microfacies (sample 23) and the *Saccocoma–Globochaete* microfacies (samples 24 and 25). Of other biogenic elements occur there: shells of juvenile bivalves, aptychi, shells of juvenile ammonites, benthic foraminifers, ostracods and crinoid fragments. At the base of the unit (sample 23) the biogenic fragments are locally phosphatised.

The limestones rich in columnar stromatolites occur in a somewhat higher part of the unit, from about 0.75 m up to about 3.7 m above its base. A continuous change in the microfacies is observed from the base of the unit upwards: from *Saccocoma* packstone (sample 26), through *Saccocoma–Globochaete* packstone (sample 27, Pl. 10: 5), and *Globochaete–Saccocoma* packstone (sample 28, Pl. 10: 6), up to radiolarian–*Saccocoma–Globochaete* wackestone (sample 29).

The nodular limestones dominate in upper part of the unit. Stromatolites tend to be rare here and flat in shape. The limestones are wackstones to packstones showing variable proportions of the occurrence of the main microfossils: *Saccocoma*, *Globochaete* and radiolarians (Fig. 5, samples 30–37). Other biogenic elements include: juvenile ammonite shells (frequent), ophiurids, aptychi, foraminifers and an echinoid fragment.

Unit 3E – pink pelitic limestones (between 23.9–41.0 m of the Neresnitsa limestone section)

The unit is well characterized by the total disappearance of marly intercalations, and by a small contrast appearing between the particular parts of the succession which has developed during various stages of early diagenesis. This has resulted in the appearance of the “intraclastic” structure of the rock, well visible on the polished faces of the quarry, and noted commonly in thin sections. This facies is close to the pseudonodular facies of Martire (1996). The limestones are biomicritic wackestones. Generally in the whole interval there is a marked abundance of calpionellids and *Globochaete alpina* Lombard (Pl. 11: 1). Only the lowermost sample (no. 38) represents the *Saccocoma* microfacies. The early diagenetic “clasts” are encountered in the bulk of the samples studied, and they show commonly the presence of calcified radiolarians. The uppermost part of unit 3E, consists of micritic limestones represented by wackstones of the calpionellid – *Globochaete* microfacies below (samples

53 and 54) which are replaced higher by wackstones of the radiolarian-calpionellid microfacies (samples 55 and 56). The calpionellids are everywhere very common. Tiny dark coloured grains – probably of volcanic ash (0.01 mm in size, and smaller) – have been recognized in samples 41 and 42.

Unit 4 – basaltic rocks (between 41.00–47.15 m of the limestone section)

The basaltic rocks with pillow lavas are 6 m thick. Their contact with the underlying limestones is sharp and diabasic dykes also penetrate the topmost part of the limestones of unit 3E.

Unit 5 – limestones with volcanogenic bed (between 47.15–50.65 m of the limestone section)

Subunit 5a – fossiliferous limestones rich in a benthic fauna: brachiopods, bivalves, crinoids (also calyxes) and solitary corals. Ammonites are also present. This subunit is 1.6 m in thickness.

Subunit 5b – volcanic ash 0.5 m in thickness.

Subunit 5c – 1.4 m thick yellow pelitic limestones representing the biomicrite wackstone of the calpionellid microfacies. Less frequently there occur benthic foraminifers, calcified radiolarian tests, sponge spicules, bivalve shell fragments, crinoid ossicles, aptychi and juvenile ammonite shells.

Unit 6 – breccia limestones (between 50.65–54.00 m of the limestone section)

These are limestones rich in basaltic and limestone clasts. The limestones are biomicrite wackestone (sample 58, Pl. 11: 5) with abundant calcified radiolarian tests and calcareous dinocysts. Calpionellids are also common. The limestone contains moreover fragments of bivalves, gastropods, crinoids, echinoid spines, juvenile ammonite shells, ostracods, benthic foraminifers as well as rare planktonic foraminifers. Some of the pelitic limestone clasts contain Upper Tithonian and Lower Berriasian calpionellids. The visible part of the unit is about 3.5 m thick.

BIOSTRATIGRAPHY AND CHRONOSTRATIGRAPHY

The biostratigraphy of the section is based on different groups of fossils. Ammonites play the leading role in the biostratigraphy of the Jurassic and Cretaceous systems. Ammonites occur commonly in the nodular limestones (units 3B and 3D) and make possible the recognition of the Bathonian, Oxfordian and Kimmeridgian stages, and their detailed subdivision. In the other lithological units of the section studied the ammonites are very rare or missing; in such case we have used other fossil groups (organic-walled dinoflagellates, calcareous dinoflagellates and capionellids) for the chronostratigraphical interpretation of the deposits (Fig. 5). Problems appeared, however, with the precise correlation of the boundaries of some substages, or even stages, when defined on different groups of fossils. It should be remembered that the correlation of the standard ammonite subdivisions with those based on other groups of fossils is not precisely established and explicitly accepted in every part of the stratigraphic column. This is also the case with some boundaries which are referred to the calpionellid zonation (Remane *et al*., 1986) or the calcareous dinoflagellate zonation (Reháková, 2000). Hence in our Fig. 5 we have indicated with graphic symbols the group of the fossils on which the relevant boundary in the section studied has been recognized; if the boundary bears no fossil symbol – it means it is distinguished on ammonites – and the standard ammonite zonation. Existing ideas concerning correlation of the particular biostratigraphical subdivisions with the standard division based on ammonites are discussed in the relevant parts of the text below.

?LOWER JURASSIC – LOWER PART OF THE MIDDLE JURASSIC

In the lower part of the succession studied at Veliky Kamenets ammonites are very rare. Only two fragments of strongly involute, and compressed phylloceratids representing possibly the genus *Zetoceras* have been found, including one well localized in the section – in the oyster lumachelle layer within the siltstones and shales of unit 2, 6.6 m from its base (Fig. 3; Pl. 6: 1). The ammonites of the genus are known to occur from the Sinemurian to the Bajocian (see Arkell *et al*., 1957), which is in general agreement with the dating of the younger deposits in question based on organic-walled dinoflagellate cysts.

Five samples have been taken from the black shales of unit 2 – from 4.20 m (sample 2.1), through 2.10 m (sample 2.2), 1.10 m (sample 2.3), 0.80 m (sample 2.4) up to 0.40 m (sample 2.5) below the top of the unit. Three of them (samples 2.1, 2.2 and 2.4) yielded organic dinoflagellate cysts (Fig. 6): sample 2.1 – *Scriniocassis priscus* (Gocht), *Nannoceratopsis gracilis* Alberti, *Phallocysta elongata* (Beju) and *Moesodinium raileanui* Antonescu; sample 2.2 – *Kallosphaeridium praussi* Lentin et Wiliams, *Nannoceratopsis gracilis* and *N. dictyambonis* Riding; sample 2.4 – *Pareodinia ceratophora* Deflandre, *Nannoceratopsis gracilis*, *Phallocysta elongata*, *Moesodinium raileanui*, *Mancodinium semitabulatum* Morgenroth (Pl. 1: 1–9).

The assemblage is fairly uniform and indicates generally the stratigraphical interval from the uppermost Toarcian (ammonite Levesquei Zone *sensu anglico* – *cf*. Elmi *et al*.,

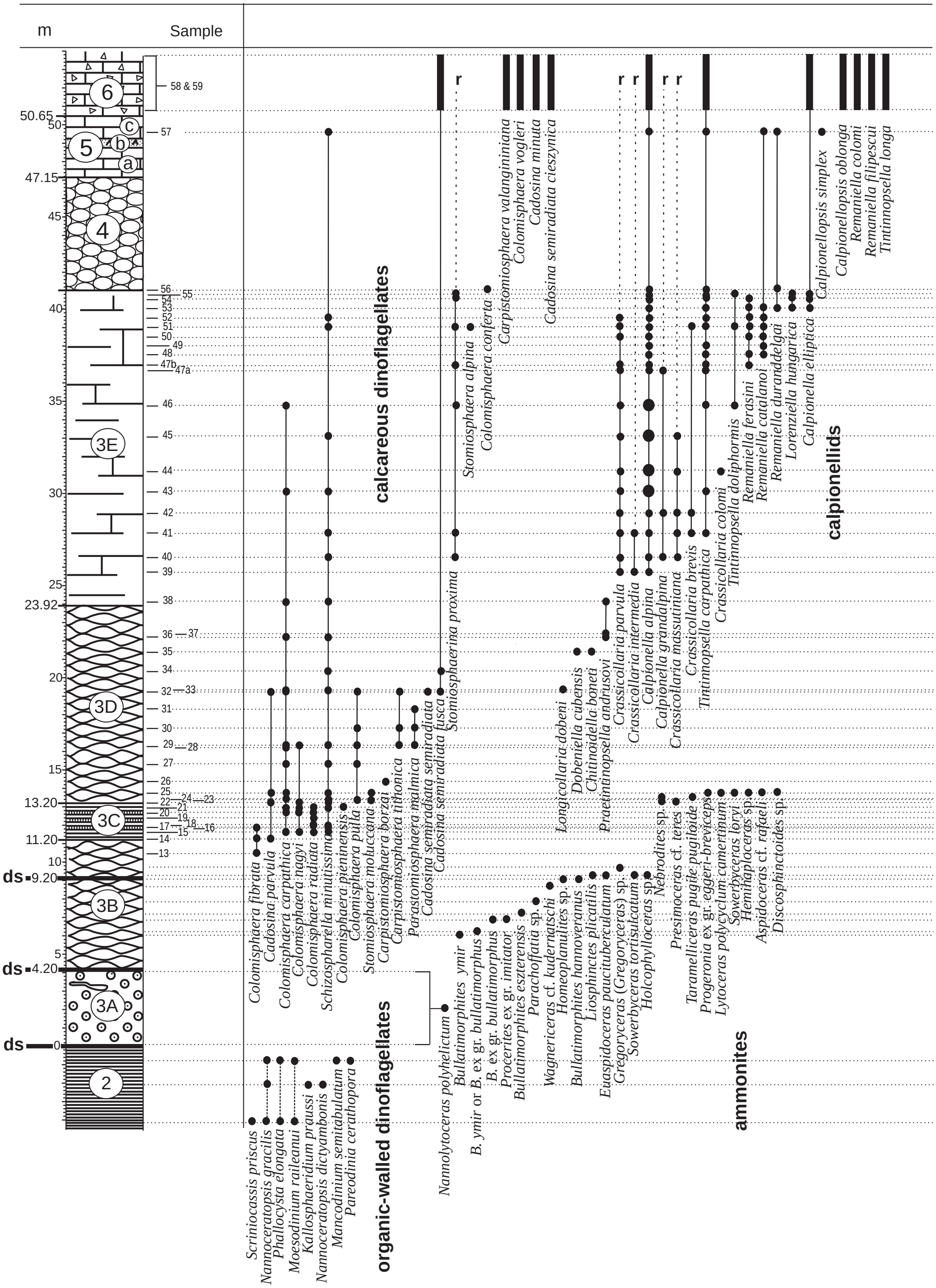
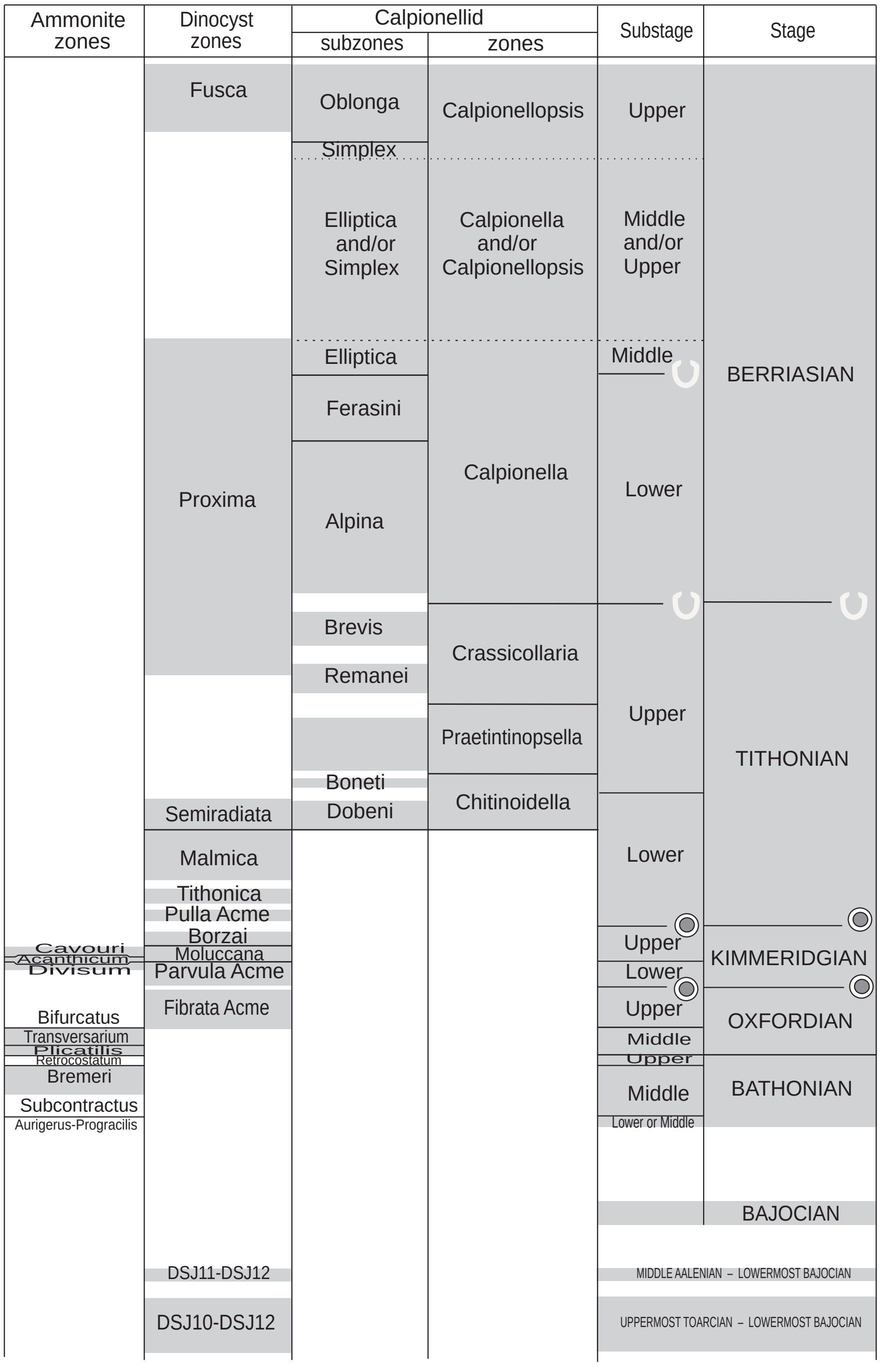


Fig. 5. Ammonite and microfossil (dinoflagellate and calpionellid) distribution

r – fossils in clasts, symbols of tintinnids and calcareous dinoflagellates mark the boundaries of chronostratigraphical units indicated by these fossil
ds – discontinuity surface



in the Veliky Kamenets section and its chronostratigraphical interpretation

groups; ammonite zone names put on a white substrate mean zones identified by ammonites found in the rubble; lithologies are explained in the text;

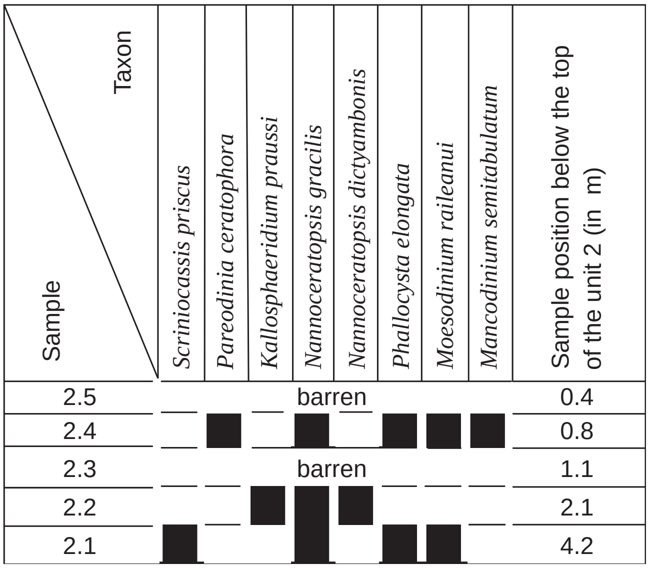


Fig. 6. Organic-walled dinocyst distribution in the upper part of unit 2 in the Veliky Kaments section (see Fig. 5)

1994: fig. 2) to the lowermost Bajocian (ammonite Discites Zone) as proved especially by the occurrence of *Phallocysta elongata* (samples 2.1 and 2.4) and *Nanoceratopsis dictyambonis* (sample 2.2) – Fig. 6. The occurrence of *Pareodinia ceratophora* in sample 2.4 (0.8 m below the top of the unit 2), however, indicates additionally that the deposits cannot be older than the Middle Aalenian (ammonite Murchisonae Zone) – see Riding and Thomas (1992). It should be also remembered that the appearance of *Phallocysta elongata* and *Nanoceratopsis dictyambonis* as recognized in two lowest samples in the section studied (samples 2.1 and 2.2 – from 4.20 to 2.10 m below the top of unit 2) defines DSJ10 zone (Poulsen, Riding, 2003). This zone may be correlated with the stratigraphical interval denoted by ammonite zones – from the Levesquei Zone (uppermost Toarcian) to the Opalinum Zone (lowermost Aalenian) – see Poulsen and Riding (2003).

From the aforgoing, it becomes evident that the oldest deposits studied of unit 2 (from 4.20 to 2.10 m below the top of the unit) correspond to the uppermost Toarcian (Levesquei Zone) and/or the lowest Aalenian (Opalinum Zone), whereas the younger deposits (at about 0.8 m below the top of the unit 2) correspond to the Middle Aalenian (Murchisonae Zone) and/or the lowermost Bajocian (Discites Zone) – Fig. 5.

Poorly preserved ammonites of the genus *Nannolytoceras*, and referred to as *N. polyhelictum* (Böckh), have been recognized in the crinoidal limestones of unit 3A. Their occurrence suggests the Bajocian age of the deposits in question (Lewandowski *et al.*, 2005).

BATHONIAN

The Bathonian ammonite assemblage has a Submediterranean character, dominated by Tulitidae and Perisphinctidae. The biostratigraphical subdivision of the Bathonian Stage used here is that summarized by Mangold and Rioult (1997) for the Submediterranean Province.

The lowermost part of the ammonitico rosso (unit 3B) did not yield any ammonite fauna. The first fauna to be collected was from the interval between 1.8 and 2.5 m above the base of the unit. The ammonites belong essentially to the genus *Bullatimorphites* (Pls 2–4). A single specimen collected around 1.8 m above the base represents the internal whorls of a relatively involute form with thin, dense primary ribbing, resembling *B. (B.) ymir* (Oppel) – Pl. 3: 1; this species is indicative of the uppermost Lower Bathonian and lower Middle Bathonian. Another two more complete but corroded, adult specimens were collected approx. 2.0 m above the base of unit 3B. The better preserved specimen shows evolute internal whorls relatively more often than the preceding one, with dense radiate to slightly prorsiradiate ribbing, which becomes coarser on the last whorl preserved. Its overall morphology ranges somewhere between *B. (B.) ymir* and *B. (B.)* ex gr. *bullatimorphus* Buckman – Pl. 2: 4. A younger fauna was collected approx. 2.6 m above the base of unit 3B. It consists of a corroded specimen belonging to *Procerites (P.)* ex gr. *imitator* (Buckman) – Pl. 5: 1. This species shows a rather large stratigraphic extent (Zigzag Zone to Retrocostatum Zone), and probably encompasses several morphologically very similar forms. It is associated with adult *B. (B.)* ex gr. *bullatimorphus* (Pl. 3: 3), similar but smaller than both the type specimen and the intermediate specimen from the preceding faunal association.

A younger ammonite fauna was collected from a level approx. 2.9 m above the base of unit 3B. It also consists of one relatively small-sized, adult *Bullatimorphites*. This specimen is partially comparable with the *B. (B.) eszterensis* (Böckh) – Pl. 2: 1, mainly concerning its size, evolute coiling and primary ribbing. On the other hand, the secondaries are rursiradiate, a feature unknown in the genus *Bullatimorphites*. Due to the relatively bad preservation it is impossible to state whether this feature is a part of the normal ornamentation or only a teratologic anomaly. *B. (B.) eszterensis* is a taxon of the Bremeri Zone. The associated fauna is badly preserved; one small fragment of *Oxycerites* or *Oppelia* and small fragment of *Adabofoloceras* sp. were distinguished.

Another ammonite was collected from the rubble some 3.6 m above the base of unit 3B. It is a heavily corroded evolute macroconch. Only radial primary ribs are visible on the internal cast. The specimen can be assigned roughly to some *Parachoffatia* (Pl. 5: 2), with the stratigraphic range of the genus from Middle to Upper Bathonian (Mangold, 1971;

Sandoval, 1983). A small fragment of a perisphinctid ammonite with very strong primary ribs, probably belonging to the relatively strongly ornamented *Wagnericeras* cf. *kudernatschi* (Lissajous) – Pl. 3: 4, characteristic of the uppermost Middle Bathonian (Bremeri Zone) has been found at approx. 4.3 m above the base of unit 3B.

A small fragment of a densely ribbed perisphinctid ammonite was collected approx. 5 m above the base of unit 3B. It is too fragmentary to be determined to the species level. The details concerning the division of the ribs are not visible, some ribs seem to bifurcate and some to trifurcate. The primary ribs are rectiradiate, and the division point is near the 1/2 of the flanks. It approaches the genus *Homoeoplanulites* (Pl. 2: 2).

It is also worth noting the presence of *Bullatimorphites (B.)* cf. *polypleurus* (Buckman) – Pl. 2: 3; *B. (B.) costatus* Arkell – Pl. 3: 2; and *Epistrenoceras* sp., unfortunately all collected from the rubble. These ammonites indicate: the presence of the Middle Bathonian Subcontractus Zone (the first one), the upper part of the Bremeri Zone (the second one, see Mangold, Gygi, 1997), and the Upper Bathonian Retrocostatum Zone (the third one). The specimen described and figured by Rakús (1990, pl. 4, fig. 3) as *Bullatimorphites (B.)* ex gr. *bullatus* (d'Orbigny) from the "lower part of the ammonitico rosso formation (as written on the specimen)" most probably belongs to *B. (Kheraiceras) hannoveranus* (Roemer) – Pl. 4, thus indicating the Upper Bathonian Retrocostatum Zone and not Lower Callovian as suggested by this author. Another specimen referred to by the same author as *Bullatimorphites (B.)* ex gr. *bullatus* and coming from the layer just below the discontinuity surface subdividing unit 3B into its lower (Bathonian) and upper (Oxfordian) parts is not preserved in Rakus's collection (housed in the Slovak National Museum in Bratislava), and thus the Early Callovian age of the uppermost layers of the Middle Jurassic part of the section can not be verified.

OXFORDIAN

The Oxfordian Stage is regarded herein according to its Submediterranean interpretation, markedly different from that of the Boreal and Subboreal ones (Matyja *et al*., 2006). The subdivision of the Middle Oxfordian is after Głowniak (2002) who reinterpreted the Plicatilis Zone and the Transversarium Zone as defined by two successive natural assemblages of ammonites of the family Perisphinctidae: *Kranaosphinctes* (M) – *Otosphinctes* (m) for the Plicatilis Zone, and *Perisphinctes* s. str. (M) – *Dichotomosphinctes* (m) for the Transversarium Zone. The base of the Upper Oxfordian is coeval with the base of the Bifurcatus Zone, defined by appearance of a younger group of perisphinctids – *Perisphinctes* s. str. (M) and *Dichotomoceras* (m), with the Wartae Subzone interpreted as the basal subzone of the Bifurcatus Zone (Głowniak, 2006).

The nodular limestones of the upper part of unit 3B, directly above a marked discontinuity surface with Fe-Mn oxides crusts, yielded the Oxfordian ammonites. Close to the surface has been found the perisphinctid ammonite (Pl. 6: 2) belonging to the genus *Liosphinctes*. Although fragmentarily preserved, it can be attributed to the group of forms related to *Liosphinctes plicatilis* (Sowerby) and its allies known from the Plicatilis Zone of the Middle Oxfordian (cf. Głowniak, 2002). Another ammonite found in the rubble close to the discontinuity surface (in between 0 m to about 0.8 m above the surface) is *Euaspidoceras paucituberculatum* (Arkell). The specimen (Pl. 6: 3) is about 150 mm in diameter and shows the sparsely placed strong tubercles characteristic of the species (*cf*. Arkell, 1940). The species is known to occur in the lower part of the Middle Oxfordian – in the Plicatilis Zone and/or in the lower part of the Transversarium Zone (*cf*. Cecca, Savary, 2007). A fragment of a large heavy-ribbed *Gregoryceras* (*Gregoryceras*) – Pl. 6: 4, comes at 0.52 m above the surface in question: its presence indicates either the Middle Oxfordian (Plicatilis or Transversarium zones), or the lowermost Upper Oxfordian (Bifurcatus Zone) – *cf*. Gygi (1977). A single specimen found in the rubble, but coming from the lower part of the interval studied, is referred to as *Perisphinctes* (*Dichotomoceras*) cf. *bifurcatus* (Quenstedt): it is about 90 mm in diameter, and shows evolute coiling (at D[1] = 90 mm, Wh = 31, Ud = 45.5), and a rectangular whorl section, with ribbing typical of the subgenus: moderately dense on the outer whorl (about 47 to 50 primaries at 80 mm and 90 mm diameters, respectively), but unfortunately not visible on the inner whorls (Pl. 6: 5; *cf*. Melendez, 1989). The species *P*. (*D*.) *bifurcatus* is indicative of the upper part of the Bifurcatus Zone – the Grossouvrei Subzone. Some phylloceratid ammonites have been found about 0.2 m above the discontinuity surface: these include *Holcophylloceras* sp., and *Sowerbyceras tortisulcatum* (d'Orbigny, 1849) – Pl. 6: 6 – the latter is known already from Lower and Middle Oxfordian.

The whole assemblage of ammonites found directly above the discontinuity surface up to not more than 0.8 m, indicates that the deposits belong to the Middle Oxfordian, and the lowermost part of the Upper Oxfordian (Bifurcatus

[1] The following abbreviations are used in descriptions of the ammonites: D – diameter of specimen in mm; Wh – whorls height as percenatage of D; Ud – umbilical diameter as percentage of D; Wb – whorl breadth as percentage of D; PR – number of primary ribs per whorl

Zone). The highest part of the nodular limestones of unit B did not yield any ammonites, but the common occurrence of the calcareous dinocyst *Colomisphaera fibrata* (Nagy) in the upper part of unit 3B (nodular limestones, sample 13 on Fig. 5), as well as at the base of unit 3C (cherty limestones/ radiolarites – sample 14) – Pl. 9: 2, together with *Cadosina parvula* Nagy, suggests the Late Oxfordian age of the deposits which may correspond to the Fibrata Acme Zone (Reháková, 2000). Still higher samples of unit 3C yielded some calcareous dinocysts, inconclusive, however, for detailed dating of the deposits.

KIMMERIDGIAN

Ammonites have been found in the lower part of unit 3D (upper nodular limestones of the ammonitico rosso type), from its base, through 0.50 m, and 0.75 m above the base of the unit (Fig. 5).

The oldest assemblage of ammonites has been found at the base of the nodular limestones (unit 3D) directly above the cherty limestones (unit 3C). It consists of poorly preserved and specifically undeterminable *Nebrodites* sp., and a single, fragmentarily preserved simoceratid ammonite (Pl. 6: 7). The latter is 65 mm in diameter, and shows very evolute coiling (at D = 65mm, Wh = 23, Ud = 58). The ribbing consists of simple, rather densely placed, fairly strong ribs (about 27 ribs per half a whorl at D = 65 mm). The specimen reveals all the features of the genus *Presimoceras*, being especially close to the species *Presimoceras teres* (Neumayr) (see Neumayr, 1873; Sarti, 1990), and it is referred to as *P.* cf. *teres* (Neumayr). The species is known to occur in the Herbichi Zone corresponding approximately to the Divisum Zone *sensu lato* (Sarti, 1993). The occurrence of the form in question, close to *P. teres*, together with *Nebrodites*, suggests the upper part of the Divisum/Herbichi Zone (*cf.* Sarti, 1993).

Two additional specimens represent the genus *Nebrodites.* A small, fragmentarily preserved, and specifically undeterminable specimen has been found somewhat above the base of unit 3D. Another specimen (Pl. 6: 8) is a fragment of a whorl, about 30 mm in height, and still septate: the original specimen could attain at least 150 mm in diameter. It has been found in the rubble, coming from the lower part of unit 3D. The fairly dense ribbing, presence of single and biplicate ribs – the latter bifurcating at about the middle of the whorl height, and the high-oval whorl section with flattened whorl sides, indicate that the specimen belongs to the species *Nebrodites peltoideus* (Gemmelaro, 1872) – *cf.* Ziegler (1959), Sarti (1993, 2002a). *N. peltoideus* is known from the upper part of the Divisum/Herbichi Zone and the Acanthicum Zone (Sarti, 1993, 2002a).

A fairly well preserved specimen of *Taramelliceras* (*Taramelliceras*) found 0.5 m above the base of unit 3D consists of the phragmocone (up to about 60 mm diameter) and the partly preserved body-chamber one-third of a whorl long (Pl. 7: 1). The coiling is less strongly involute than commonly encountered in the subgenus (at D = 70 mm, Wh = 43, Ud = 22.5). Well developed ventrolateral tubercles and the presence of sinuous ribs on the whorl side show close affinity of the specimen in question with *Taramelliceras* (*Taramelliceras*) *pugile pugiloide* (Canavari, 1896) as *e.g.* illustrated by Gemmelaro (1882 and reproduced 2002: pl. 6: 2a–c; see also Pavia, 2002a, fig. 152). The subspecies is known from the Acanthicum Zone up to the Beckeri Zone of the Upper Kimmeridgian (Sarti, 1993; Pavia, 2002a).

Two specimens of the family Ataxioceratidae attributed to the genus *Progeronia* have been found 0.70–0.75 m above the base of unit D. A smaller specimen (Pl. 7: 2) shows moderately evolute coiling (at D = 98 mm, Ud = 47, Wh = 31.6), a low oval whorl section, and rather dense ornamentation consisting of about 55 primary ribs per whorl. The primary ribs are biplicate, and later also polygyrate. Two shallow constrictions at the end of the last whorl, and an associated increase in whorl height, as well as some crowding of the ribs, indicate the proximity of the final aperture, and suggest the specimen represents the microconch. Another specimen (Pl. 7: 3) is larger, attaining about 130 mm in diameter, but shows similar coiling (at D = 130 mm, Ud = 46, Wh = 30.8) and similar low oval whorl section (Wb = 29.2). The ribbing is less dense: at D = 130 mm, PR = 43, at D = 100 mm, PR = 45. The primary ribs on the last whorl are polygyrate with three to four secondary ribs per primary. The aperture is not preserved. The specimens studied can be compared with *Progeronia eggeri* (Ammon, 1875), the holotype of which is a wholly septate specimen 130 mm in diameter (*cf.* Geyer, 1961, pl. 7: 1; see also Schairer, 1974, p. 61), and also with *Progeronia* (*Hugueninsphinctes*) *breviceps* (Quenstedt, 1887), the holotype of which is a large microconch with lappets about 165 mm in diameter (see Quenstedt, 1887, pl. 103: 2; Atrops, 1982, pl. 44: 1). Both of these forms seems closely related (see synonymy of *P. eggeri* in: Geyer, 1961, p. 32), and if the type of *P. eggeri* is a macroconch, they could even represent the corresponding macro- and microconch. The specimens studied may be thus referred to as *Progeronia* ex gr. *eggeri* (Ammon) – *breviceps* (Quenstedt). These species have poorly recognized stratigraphical ranges, being generally interpreted as indicative of the upper part of the Divisum Zone, and the whole Acanthicum Zone (*cf.* Atrops, 1982; Sarti, 1993; Moliner, Olóriz, 1999; *cf.* also Schick, 2004).

Some lytoceratoid ammonites have been found in the studied interval. These include *Lytoceras polycyclum* Neumayr, represented by its less evolute morphological variant or subspecies *Lytoceras polycyclum camertinum* Canavari, 1897 (Pl. 7: 4). This form is well known in the Mediterranean Kimmeridgian (*e.g.* Sarti, 1993; Pavia, 2002b). The phylloceratids include one specimen of *Sowerbyceras* found 0.75 m above the base of unit 3D. It is an incomplete specimen about 40 mm in diameter consisting of the phragmocone (up to 35 mm diameter) and an initial part of the body chamber (Pl. 7: 5). Two constrictions are visible: one, poorly marked, on the phragmocone, and one on the body chamber. The constrictions maintain their depth and run almost straight on the ventral side of whorl, features typical of *Sowerbyceras loryi* (Munier Chalmas *in* Pillet & de Fromental, 1875). The species *S. loryi* occurs from the Divisum/Herbichi Zone up to the Beckeri Zone (Sarti, 1993, 2002b), but its acme is noted in the middle of the Acanthicum Zone (Sarti, 1993; Caracuel *et al.*, 1998).

This assemblage of ammonites found in the lower part of the nodular limestones (unit 3D) indicates thus the Acanthicum Zone, and possibly uppermost part of the Divisum/Herbichi Zone at the base of the rock-unit in question.

It should be mentioned, however, that some ammonites found at the top of the interval in question, about 0.75 m above the base of unit 3D, suggest a somewhat younger stratigraphical position. These include an evolute oppeliid, about 65 mm in diameter, represented by a fragment of outer whorl, which shows the sparsely placed simple ribs which end in rounded ventrolateral tubercles. This specimen can be referred to as *Hemihaploceras* sp. (Pl. 7: 6). The genus *Hemihaploceras* appears in the Cavouri Zone and continues up into the Beckeri Zone of the Upper Kimmeridgian (Olóriz, 1978; Caracuel *et al*., 1998). Two specimens of the genus *Aspidoceras* have been also found at the same level. The larger specimen is poorly preserved and specifically unidentifiable, but the smaller specimen, consisting of the phragmocone and initial part of the body chamber, 52 mm in diameter, is better preserved: it shows a deep and narrow umbilicus (Ud = 29), and a low oval, depressed whorl section (Wh = 48, Wb = 61) with two rows of sparsely placed tubercles located well below the mid-height of whorl. These features are encountered in the species *Aspidoceras rafaeli* (Oppel, 1863) (see Checa, 1985), and the specimen in question may be referred to as *A.* cf. *rafaeli*. The species *A. rafaeli* appears in the Upper Kimmeridgian – in the Cavouri Zone, and it continues upwards into the Tithonian (Sarti, 1993). Additionally, some fragmentary specimens of Ataxioceratidae showing dense biplicate ribbing somewhat reminiscent of that of the genus *Discosphinctoides* Olóriz, have been found at 0.75 m above the base of unit 3D. The genus *Discosphinctoides* occurs in the Acanthicum (Compsum) Zone and the Cavouri Zone of the Upper Kimmeridgian (*cf.* Olóriz, 1978). The ammonite records from the level at 0.75 m above the base of unit 3D suggest, thus, the presence of the Cavouri Zone of the Upper Kimmeridgian.

Only the uppermost part of unit 3C (down to few centimeters below its top – sample 22) yielded a rich assemblage of calcareous dinocysts consisting of abundant *Cadosina parvula* Nagy (Pl. 9: 1, 10: 4) accompanied by other forms such as *Colomisphaera pieniniensis* (Borza) – Pl. 9: 3, *Schizosphaerella minutissima* (Colom) and others which are indicative of the Parvula Acme Zone (Reháková, 2000). This zone correlates with the Lower Kimmeridgian (Fig. 5). Because, directly above the dated sample, at the base of the unit 3D, occur both ammonites (see below) and calcareous dinocysts indicative of the Upper Kimmeridgian, it should be concluded that a large part of unit 3C (cherty limestones) below the dated sample corresponds to the Lower Kimmeridgian.

The occurrence of a calcareous dinocyst assemblage: *Stomiosphaera moluccana* Wanner (Pl. 9: 9), *Colomisphaera pulla* (Borza), *C. carpathica* (Borza), *Cadosina parvula* Nagy, *Schizosphaerella minutissima* (Colom) indicates the presence of the Moluccana Zone of the Upper Kimmeridgian (see Reháková, 2000) in the lowermost part of unit 3D (samples 23–25). This fact clearly confirms the statement of Reháková (2000), that the Moluccana Zone coincides with the ammonite Acanthicum Zone of the Upper Kimmeridgian, and that the boundary between the Acanthicum and Cavouri zones runs between the Moluccana and Borzai zones.

Younger deposits, about 1 m above the base of unit 3D (sample 26), yielded: *Carpistomiosphaera borzai* (Nagy) – Pl. 9: 10, indicative of the Borzai Zone of the Upper Kimmeridgian.

TITHONIAN

Still higher, at about 2 m above the base of unit 3D (sample 27), there occurs *Colomisphaera pulla* (Borza) – Fig. 5; Pl. 9: 11–12, indicating the presence of the Pulla Zone of the lowermost Tithonian. These data show that the boundary between the Kimmeridgian and Tithonian runs in the lower part of unit 3D, about 1.2 to 2.1 meters above its base.

The rich assemblage of calcareous dinocysts found at about 3 metres above the base of unit 3D (samples 28–29) consists of *Carpistomiosphaera tithonica* Nowak (Pl. 9: 13), *Colomisphaera nagyi* (Borza), *C. carpathica* (Pl. 9: 5), *C. pulla*, and *Schizosphaerella minutissima* and indicates the Tithonica Zone of Lower Tithonian (Rehákova, 2000; *cf.* also Reháková, Wierzbowski, 2005).

The younger nodular limestones of unit 3D, about 4–5 meters above the base of the unit (samples 30–32), yielded the calcareous dinocysts *Cadosina semiradiata semiradiata* Wanner (Pl. 9: 16); *Parastomiosphaera malmica* (Borza) – Pl. 9: 14, *Colomisphaera pulla* (Borza) and *Carpistomiosphaera tithonica* Nowak which are indicative of the Malmica Zone of the Lower Tithonian (Reháková, 2000).

On the other hand, sample no. 33 yielded the first calpionellids – *Longicollaria dobeni* (Borza), indicative of the Dobeni Subzone of the standard Chitinoidella Zone of the Middle Tithonian in the Western Carpathian area (Reháková, 2002: *cf.* also Reháková, Wierzbowski, 2005). A similar stratigraphic interval is suggested by the occurrence of the calcareous dinocysts *Cadosina semiradiata semiradiata* Wanner – and *Schizosphaerella minutissima* (Colom) – Pl. 9: 4, found about 7 m above the base of unit 3D (sample 34), and corresponding possibly to the dinoflagellate Semiradiata Zone (Reháková, 2000).

The occurrence of calpionellids – *Dobeniella cubensis* (Furazola-Bermudez) and *Chitinoidella boneti* Doben (Pl. 8: 1) in sample no. 35, indicates the Boneti Subzone representing the upper part of the Chitinoidella Zone of the Middle Tithonian (Reháková, 2002). The uppermost part of unit 3D and the first few centimeters of unit 3E (samples 36–38), yielded the calpionellid *Praetintinnopsella andrusovi* Borza (Pl. 8: 2) indicative of the Praetintinnopsella Zone which covers the uppermost part of the Middle and the lowermost part of the Upper Tithonian (Reháková, 2002). According to the more recent results of an integrated study (Pruner *et al*., 2010) both the Boneti Subzone and the Praetintinopsella Zone coincide with the Upper Tithonian ammonite Microcanthum Zone. Therefore, the biozonation supported by dinocyst distribution (Borza, 1984; Reháková, 2002) should be corrected. Thus, the Malmica Zone and the Dobeni Subzone of the Chitinoidella Zone should be considered as Lower Tithonian only.

In the lower part of unit 3E (sample 39) there occur abundant calpionellids: *Crassicollaria intermedia* (Durand-Delga) dominating over *Crassicollaria parvula* Remane and *Calpionella alpina* Lorenz. These indicate the presence of the Remanei Subzone of the standard Crassicollaria Zone of the Upper Tithonian (*e.g.* Remane *et al.*, 1986).

Still in the lower part of unit 3E (samples 40–42) occur abundant calpionellids: *Calpionella alpina* Lorenz, *C. grandalpina* Nagy, *Crassicollaria massutiniana* (Colom) (Pl. 8: 3), *C. parvula* Remane (Pl. 8: 4), *C. brevis* Remane, *C. intermedia* (Durand-Delga) and *Tintinnopsella carpathica* (Murgeanu et Filipescu). These are indicative of the standard Crassicollaria Zone of the Upper Tithonian.

BERRIASIAN

Sample no. 43 yielded a younger assemblage of calpionellids consisting of abundant *Calpionella alpina* and rare *Tintinnopsella carpathica* and crassicollarians (*Crassicollaria parvula*). The composition of the assemblage plus the dominance of sphaerical forms of *Calpionella alpina* is indicative of the Alpina Subzone of the standard Calpionella Zone of the Lower Berriasian (*e.g.* Remane *et al.*, 1986). This indicates that the boundary between the Tithonian and Berriasian as defined by calpionellids runs in the lower part of unit 3E, between samples 42 and 43. Samples nos 44–47a, taken from the middle part of the unit 3E, have shown the presence of abundant *Calpionella alpina* Lorenz, along with *Calpionella grandalpina* Nagy (in the highest sample), also *Crassicollaria parvula* Remane, *C. colomi* Doben (only in the lowermost sample), *C. massutiniana* (Colom) and *Tintinnopsella carpathica* (Murg. et Filip.). This assemblage represents the Alpina Subzone of the Calpionella Zone of the Lower Berriasian (*cf.* Reháková, Michalík, 1997), but it contains some older *Crassicollaria* coming possibly from the Upper Tithonian limestones, incorporated into the micrite matrix of the Alpina Subzone of the Calpionella Zone. An enhanced water dynamic regime on the Jurassic/Cretaceous boundary interval was recently documented by Grabowski *et al*. (2010) and Michalík and Reháková (2011).

The abundant calpionellids recognized in the upper part of unit 3E (samples 47b–52), definitely prove the presence of the the Ferasini Subzone (*cf.* Reháková, 1998). The assemblage includes: *Calpionella alpina* Lorenz (Pl. 8: 5), *Tintinnopsella carpathica* (Murg. et Filip.), *T. doliphormis* (Colom), *Remaniella ferasini* (Catalano) – Pl. 8: 7, and *R. catalanoi* Pop. The presence of the *Crassicollaria parvula* Remane and *C. brevis* Remane suggests the continuation of resedimentation, which is sometimes difficult to recognize as the margins of the intraclasts are usually obscure.

A new assemblage of calpionellids appears in the uppermost part of unit 3E (samples 53–56). It consists of: *Calpionella alpina* Lorentz, *C. elliptica* Cadisch, *Tintinnopsella carpathica* (Murg. et Filip.), *T. doliphormis* (Colom), *Remaniella catalanoi* Pop (Pl. 8: 8), *R. duranddelgai* Pop, *R. ferasini* (Catalano), *Lorenziella hungarica* Knauer. The occurrence of *Calpionella elliptica* Cadisch accompanied by *Remaniella duranddelgai* Pop and *Lorenziella hungarica* Knauer (Pl. 8: 10) indicates the presence of the Elliptica Subzone of the Calpionella Zone of the Middle Berriasian (*e.g.* Reháková and Michalík, 1997; Reháková, Wierzbowski, 2005).

The micritic limestones of the upper part of unit 5 (sample 57 on Fig. 5) yielded abundant calpionellids indicating the presence of the Simplex Subzone of the Calpionellopsis Zone of the lowermost part of the Upper Berriasian. The calpionellids include: *Calpionellopsis simplex* (Colom) (Pl. 8: 11), *Remaniella duranddelgai* Pop, *R. catalanoi* Pop, *R. colomi* Pop (Pl. 8: 6), *Calpionella alpina* Lorenz, *Tintinnopsella carpathica* (Murg. et Filip.).

The biogenic limestones alternating with breccias composed of micritic limestone and basaltic clasts, representing unit 6, yielded assemblage of calpionellids consisting of: *Calpionellopsis oblonga* (Cadisch) (Pl. 8: 12), *Remaniella* *filipescui* Pop (Pl. 8: 9), *R. colomi* Pop, *Calpionella alpina* Lorentz, *C. elliptica* Cadisch, *Tintinnopsella carpathica* (Murg et Filip.), *T. longa* (Colom). This assemblage is indicative of the Oblonga Subzone of the Calpionellopsis Zone of the Upper Berriasian (*cf.* Remane *et al.*, 1986). The above mentioned assemblages of calpionellids occur together (samples 58 and 59) with calcareous dinoflagellates *Cadosina minuta* Borza, *C. semiradiata cieszynica* (Nowak), *C. semiradiata fusca* Wanner (Pl. 9: 15); *Colomisphaera vogleri* (Borza) (Pl. 9: 20) and *Carpistomiosphaera valanginiana* Borza – Pl. 9: 19, as well as rare planktonic foraminifers – *Caucasella hoterivica* (Subbotina). The presence of the calpionellids in question, together with a few fragmentarily preserved ammonites attributed to the genus *Thurmanniceras*, and the lack of *Calpionellites*, may suggest the uppermost part of the Berriasian or Lower Valanginian. The recognition of the deposits as belonging to the uppermost Berriasian results from the proposal, accepted herein, that the boundary between the Berriasian and Valanginian occurs at the base of the Pertransiens Zone (Hoedemaeker *et al.*, 2003; Reboulet *et al.*, 2006), which is coeval with the base of the calpionellid Calpionellites darderi Zone (Blanc *et al.*, 1994). There is some discrepancy, however, between this stratigraphical interpretation, and the ocurrence of the calcareous dinocyst *Carpistomiosphaera valanginiana* which according to Lakova *et al*. (1999) and Reháková (2000) appears in the Upper Valanginian. The results presented herein suggest, however, a wider stratigraphic range of the calcareous dinocyst in question.

PALAEONTOLOGICAL MICROFACIES

The microfacies and their succession in the Jurassic and Lower Cretaceous of Tethys and its margins have been studied by many authors (*e.g*. Mišik, 1979; Dromart, Atrops, 1985; Wierzbowski, 1994, Wierzbowski *et al*., 1999). These studies included also suggestions on possible causes of the mass occurrences of different groups of microfossils indicative of particular microfacies (*e.g.* Caracuel *et al*., 1997; Hudson *et al*., 2005). Herein we are describing the stratigraphical ranges of the palaeontological microfacies on a background of very precise biostratigraphy.

An analysis of microfacies was made for the units 3B–E of the Neresnitsa limestones (Figs 2, 3). The analysis focused on identifying the presence, half-quantitative determining, and the general recognition of the succession of pelagic microfossils (Fig. 7). The following microfossils are an indication of the microfacies: globochaetes, radiolarians, calpionellids, *Saccocoma*, planktonic foraminifera (*Globuligerina*) and "filaments" of bivalves (*Bositra*). Although in some parts of the section globochaetes and radiolarians are dominant or co-dominant elements of the microfacies, the fact of their wide stratigraphical range in the section studied, and also to the lack of any marked differences as recognized so far, has resulted in the main attention being paid to the other groups of pelagic microfossils, which are discussed below.

"Filaments" of bivalves *Bositra*. These occur as the dominating element of the microfacies in all the samples (nos. 8–11) from a lower part of the lower nodular limestones (3B). "Filaments" are lacking in the underlying unit 3A and also in the upper part (from sample 12 up) of unit 3B. Deposits with a "filament" microfacies belong to the Bathonian and perhaps to the upper part of the Bajocian (*cf*. Figs 3, 6).

***Globuligerina* microfacies.** This is absent in unit 3A. Planktonic foraminifers appear already in the lowermost sample of unit 3B (no. 8), and are found in samples 10 and 11 everywhere in small amounts; a mass occurrence of *Globuligerina* (foraminiferal ooze) is recorded in unit 3B, right above the lowest of a set of distinct discontinuities (sample 12 – Pl. 10: 1), about 5 m above the lower boundary of 3B unit, and the microfacies is common in samples 13 and 14. Sample 14 is located in the lowermost part of unit 3C. The chronostratigraphical range of the *Globuligerina* microfacies is restricted to the Oxfordian.

Taxonomical problems concerning the occurrence of planktonic foraminifers in the Upper Jurassic deposits of the Pieniny Klippen Belt were discussed by Hudson *et al*. (2005).

***Saccocoma* microfacies**. The roveacrinid *Saccocoma* is represented as the fitted fabric packstone of bigger skeletal elements (Pl. 10: 2) or as antler-shaped or catapult-shaped brachial plate wackestones (Pl. 10: 5, 6). The stratigraphical range of this microfacies in the Veliky Kamenets section ranges from the highest Oxfordian (sample 15) to the Remanei Subzone of the Crassicollaria Zone of the Upper Tithonian (sample 40). The skeletal elements of *Saccocoma* combine in the upper part of their range with globochaetes (Pl. 10: 5, 6), and in highest part of their range with the calpionellid microfacies.

Calpionellid microfacies. Tintinnids appear in the Veliky Kamenets section in unit 3D in upper part of the Lower Tithonian (sample 33). In considerable amounts they appear in unit 3E, in the Remanei Subzone (sample 39) of the Crassicollaria Zone – in a higher part of the Upper Tithonian (Fig. 7). In the two lowest samples (39 and 40) belonging to the Remanei Subzone, the calpionellid microfacies contributes to the *Saccocoma* microfacies (Pl. 11: 1). The occurrence of the calpionellid microfacies in unit 3D as shown

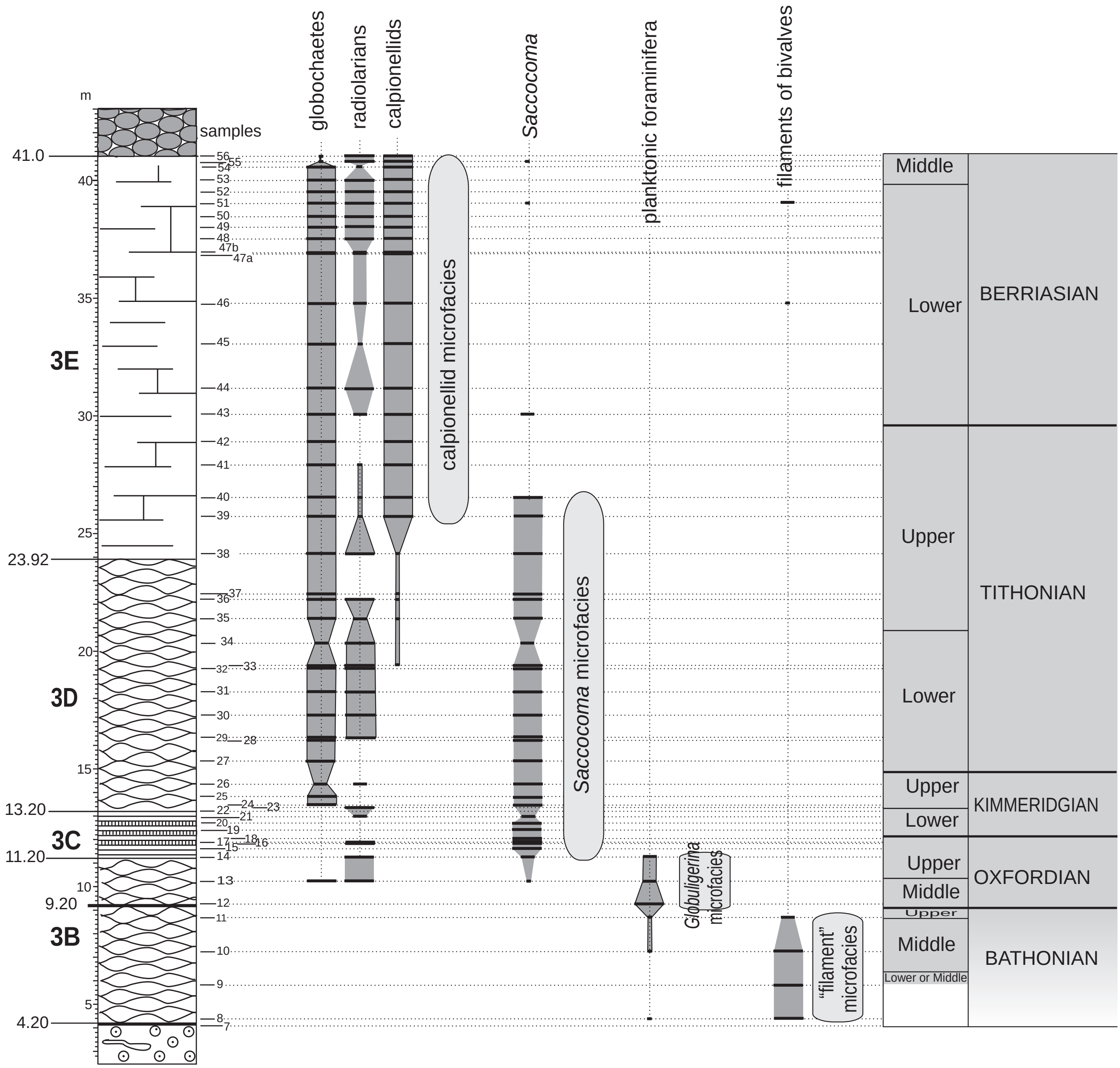


Fig. 7. Microfacies recognized in the Neresnitsa limestones in units 3B–3E

in Fig. 7 represents a fragment of its stratigraphical range because the microfacies continues upwards into units 4–6 (Figs 3, 5).

The microfacies succession as well as their stratigraphical position as recognized in the Veliky Kamenets section was reported formerly in many sections of the Pieniny Klippen Belt in western Slovakia (Mišik, 1979; Schlögl *et al*., 2006), in Poland (Myczyński, Wierzbowski, 1994; Wierzbowski, 1994; Krobicki *et al*., 2006a, b, c) as well as in eastern Slovakia (Mišik, Sýkora, 1993).

A detailed study of microfacies in relation to the chronostratigraphical scheme of the Middle Jurassic – lowermost Upper Jurassic in sections of the Pieniny Klippen Basin were presented by Wierzbowski *et al*. (1999: fig. 14), and supplemented for the Upper Jurassic by Krobicki *et al*. (2006b: fig. A50). The chronostratigraphical correlation of the *Saccocoma* microfacies and the calpionellid microfacies transition is currently presented herein.

Data concerning the succession of microfacies in the areas outside the Pieniny Klippen Basin show certain resemblance to those described herein: it is for example the case in the French Subalpine Basin (Dromart, Atrops, 1988), not to say in the Southern Alps (Trento Plateau) – Caracuel *et al*. (1997), as well as in the Western Balkan and Fore-Balkan zones in Bulgaria (Lakova *et al.*, 2007, and earlier papers cited therein), although the chronostratigraphical position of each particular microfacies differs sometimes significantly.

Summarizing the facts, the stratigraphical ranges of the particular palaeontological microfacies in the Veliky Kamenets section in Western Ukraine recognized here correspond well to those stated in sections of the Czorsztyn Succession of the Pieniny Klippen Basin of Poland and Slovakia. This makes a study of microfacies successions a useful tool for preliminary or even field-determined stratigraphical diagnosis of the Middle Jurassic to lowermost Cretaceous deposits of the whole Pieniny Klippen Basin.

DISCUSSION AND CONCLUSIONS

The Veliky Kamenets section in the eastern part of the Pieniny Klippen Belt in the Ukrainian Carpathians is composed of two parts: the lower terrigenous part (units 1–2) which represents the stratigraphical interval from the Lower Jurassic up to a lower part of the Middle Jurassic (up to the Aalenian – lowermost Bajocian), and the carbonate part of the succession (units 3A–E, distinguished herein as the Nerestnitsa limestones, as well as the overlying units 4–6 containing also volcanogenic rocks) which covers a large stratigraphical interval from the Middle Jurassic (Bathonian, and possibly also uppermost Bajocian) up to the lowermost Cretaceous (Upper Berriasian). Two main stratigraphical hiatuses are recognized: the lower one at the base of the carbonate part (at the base of unit 3A) – possibly corresponding to the lowermost Bajocian, but poorly faunistically proved; and the upper one situated within the ammonitico rosso deposits of unit 3B and covering the whole of the Callovian and Lower Oxfordian. The former may be related to the origin of the mid-oceanic Czorsztyn Ridge (*cf.* Krobicki, Wierzbowski, 2004); the latter corresponding to a marked palaeolatitudinal shift indicating a fast southerly movement of the Kamenets block and resulting in the fast opening of the oceanic domain – this phenomenon was originally treated as representing a narrower stratigraphical interval: from the Upper Callovian to the Lower Oxfordian (Lewandowski *et al*., 2005).

The succession studied, referred to as the Kamenec Succession, although showing similarity in general character of deposits to the Czorsztyn Succession from the more western parts of the Pieniny Klippen Belt, differs, however, in several features, which makes difficult the unequivocal recognition in the Veliky Kamenets section of the formal lithostratigraphic units recognized in Poland and Slovakia (*cf.* Krobicki *et al.*, 2003). This is the case for example, with of the crinoidal limestones (unit 3A) which show a similarity to some of the lithostratigraphic units such as the Smolegowa Limestone Fm., or the Krupianka Limestone Fm. in the west (presence of crinoidal limestones with a marked stratigraphical hiatus at their base), but differ in the more autochtonous character of the deposits. The ammonitico rosso deposits in the Veliky Kamenets section (units 3B – lower nodular limestones, and 3D – upper nodular limestones) sandwiched in between cherty limestones (unit 3C) show a general similarity to the tripartite fragment of the succession known from the western parts of the Pieniny Klippen Belt in Poland and Slovakia: the Niedzica Limestone Fm. (lower segment of the ammonitico rosso succession), the Czajakowa Radiolarite Fm. (composed mostly of cherty limestones), and the Czorsztyn Limestone Fm. (upper segment of the ammonitico rosso succession) (*cf.* Birkenmajer, 1977). The main differences are in the microfacies types and in the stratigraphical position of the deposits: unit 3B (lower nodular limestones) in the Veliky Kamenets section covers the stratigraphical interval from the Bathonian (and possibly uppermost Bajocian) up to the Upper Oxfordian – with a stratigrapical gap from the Callovian to Lower Oxfordian. It is developed below the stratigraphical gap in the “filament” (*Bositra*) microfacies and in the planktonic foraminifer (*Globuligerina*) microfacies above; on the other hand, the ammonitico rosso deposits of the Niedzica Limestone Fm. show the dominance of the “filament” microfacies, and span the stratigrapical interval from the uppermost Bajocian up to the uppermost Callovian/lowermost Oxfordian (Wierzbowski *et al.*, 1999). The cherty limestones (unit 3C) in the Veliky Kamenets section show the radiolarian microfacies with intercalations of packstones of the *Saccocoma* microfacies, and correspond generally to the uppermost Oxfordian – Lower Kimmeridgian, whereas the cherty limestones of the Czajakowa Radiolarite Fm. show the dominance of the radiolarian microfacies, without *Saccocoma* deposits, and are, at least mostly, of Oxfordian age (Birkenmajer, 1977).

It should be remembered that the younger deposits in the Veliky Kamenets section show, however, a marked similarity to the lithostratigraphic units recognized in the Pieniny Klippen Belt in Poland and Slovakia: the pink pelitic limestones of unit 3E are similar to those of the Dursztyn Limestone Fm. (*cf.* Birkenmajer, 1977); the fossiliferous limestones and limestone breccias of unit 5 and 6 are similar to those of the Łysa Limestone Fm., and even the stratigraphical positions of the corresponding units in both these areas seem similar (*cf.* Wierzbowski, Remane, 1992). The main difference, however, is the occurrence of the volcanogenic rocks in units 5 and 6, generally unknown in more western parts of the Pieniny Klippen Belt.

Detailed study of the other sections in the Ukrainian Carpathians seems necessary in order to recognize in detail the occurrence here of similar successions, and to make their closer correlation with those from the western and central parts of the Pieniny Klippen Belt in Poland and Slovakia.

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PLATE 1

Organic-walled Dinoflagellate cysts

Fig. 1. *Phallocysta elongata* (Beju, 1971) Riding, 1994 (photographs taken with phase contrast); sample 2.1

Fig. 2. *Mancodinium semitabulatum* Morgenroth, 1970; sample 2.4

Fig. 3. *Moesiodinium raileanui* Antonesçu, 1974; sample 2.4

Fig. 4. *Nannoceratopsis gracilis* Alberti, 1961; sample 2.1

Fig. 5. *Kallosphaeridium praussi* Lentin and Williams, 1993; sample 2.2

Fig. 6. *Pareodinia ceratophora* Deflandre, 1947; sample 2.4

Fig. 7, 8. *Nannoceratopsis dictyambonis* Riding, 1984 (Fig. 8 – photographs taken with phase contrast); sample 2.2

Fig. 9. *Scriniocassis priscus* (Gocht, 1979) Below, 1990; sample 2.1

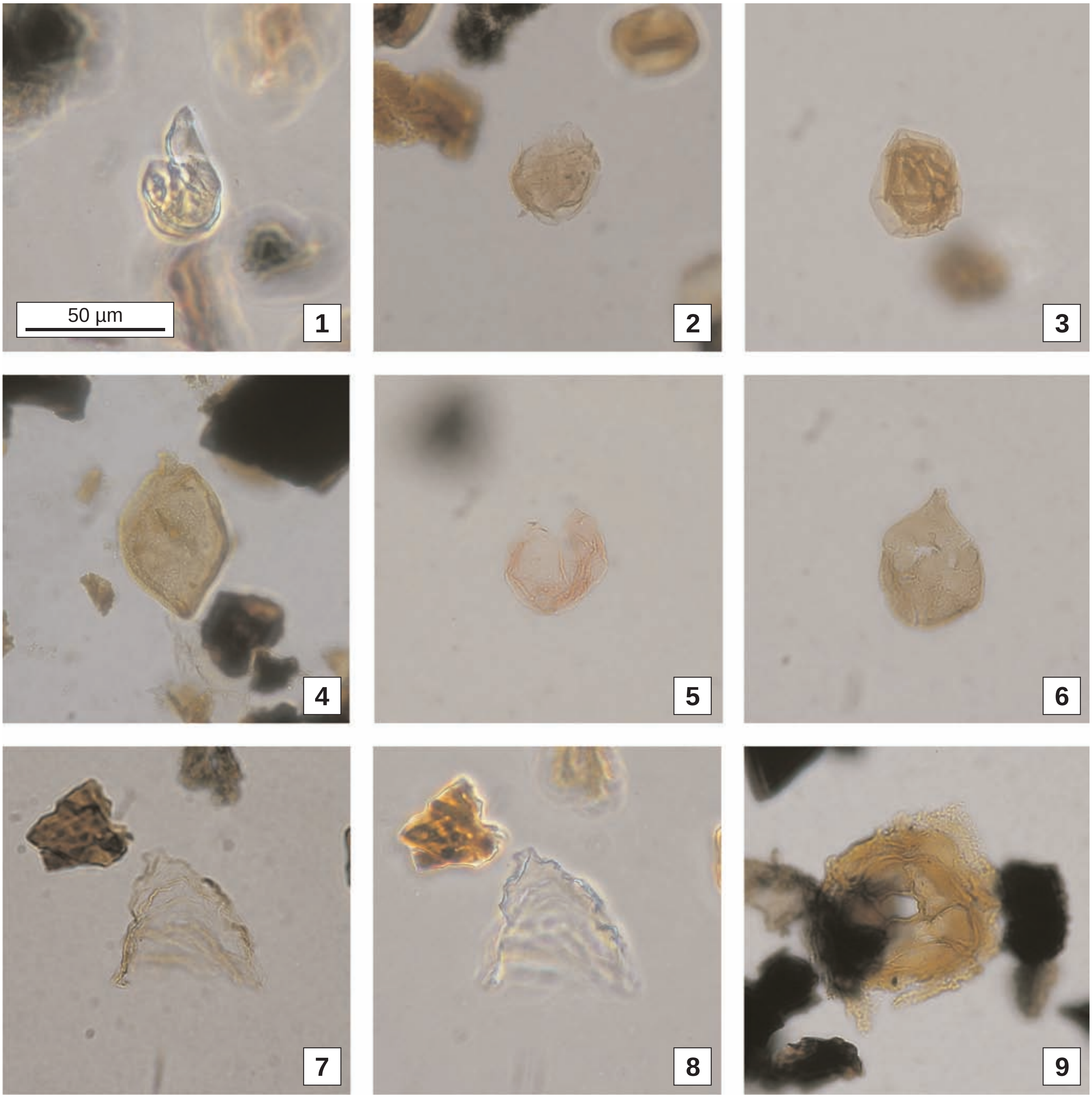
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PLATE 2

Bathonian ammonites

Fig. 1. *Bullatimorphites (B.) eszterensis* (Böckh); lower nodular limestones (unit 3B), 2.9 m above the base; SNM 2 36 829

Fig. 2. *Homoeoplanulites (H.)* sp.; lower nodular limestones (unit 3B), about 5 m above the base; SNM 2 36833

Fig. 3. *Bullatimorphites (B.)* cf. *polypleurus* (Buckman); lower nodular limestones (unit 3B), rubble; SNM 2 36830

Fig. 4. Specimen showing intermediate morphology between *Bullatimorphites (B.) ymir* (Oppel) and *Bullatimorphites (B.)* ex gr. *bullatimorphus* Buckman; lower nodular limestones (unit 3B), about 2 m above the base; SNM 2 36832

All ammonites natural size


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PLATE 3

Bathonian ammonites

Fig. 1. *Bullatimorphites (B.) ymir* (Oppel); lower nodular limestones (unit 3B), about 1.8 m above the base; SNM 2 36831

Fig. 2. *Bullatimorphites (B.) costatus* Arkell; lower nodular limestones (unit 3B), rubble; SNM 2 36828

Fig. 3. *Bullatimorphites (B.)* ex gr. *bullatimorphus* Buckman; lower nodular limestones (unit 3B), 2.6 m above the base; SNM 2 36827

Fig. 4. *Wagnericeras* cf. *kudernatschi* (Lissajous); lower nodular limestones (unit 3B), 4.3 m above the base; SNM 2 36836

All specimens natural size


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PLATE 4

Bathonian ammonites

Fig. 1. *Bullatimorphites (Kheraiceras) hannoveranus* (Roemer), specimen described and figured by Rakús (1990) as *Bullatimorphites (B.)* ex gr. *bullatus* (d'Orbigny). Lower nodular limestones (unit 3B)

Natural size

PLATE 5

Bathonian ammonites

Fig. 1. *Procerites (P.)* ex gr. *imitator* (Buckman); lower nodular limestones (unit 3B), about 2.6 m above the base; SNM 2 36835

Fig. 2. *Parachoffatia* sp.; lower nodular limestones (unit 3B), 3.6 m above the base; SNM 2 834

All ammonites natural size

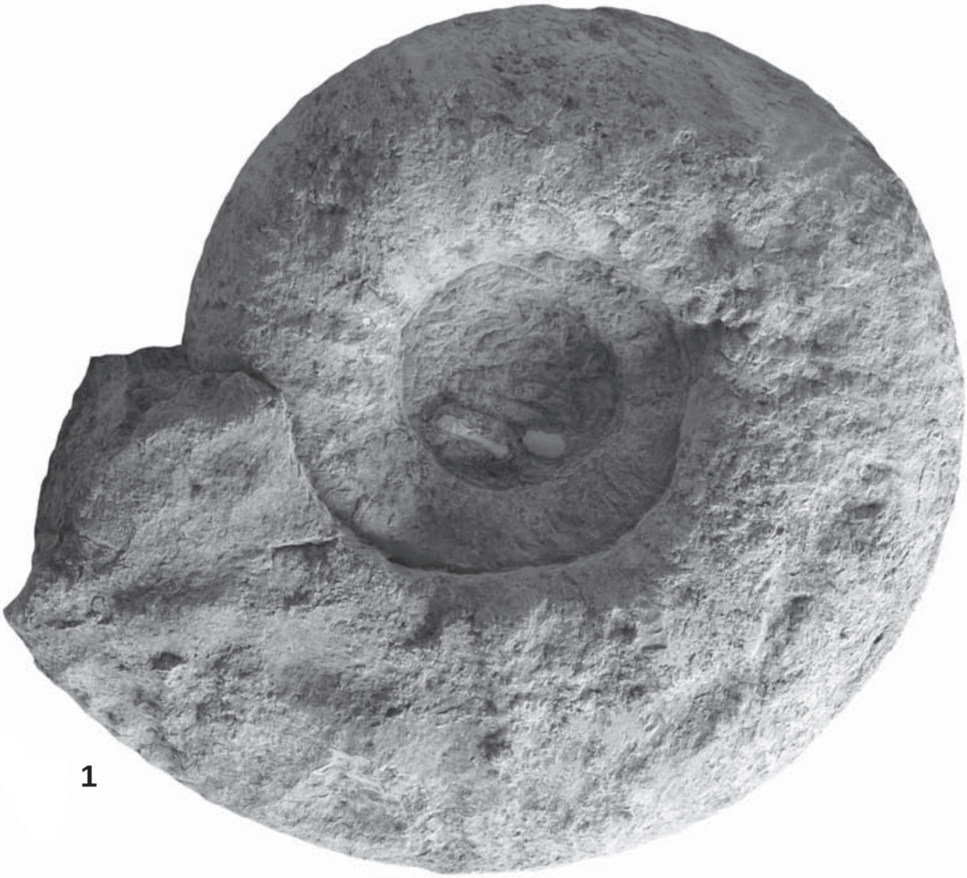

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PLATE 6

Lower Jurassic, Oxfordian and Lower Kimmeridgian ammonites

Fig. 1. *Zetoceras* sp.; shales with intercalations of siltstones/sandstones (unit 2): 15.9 m below its top; Lower Jurassic to lowermost Middle Jurassic; ZI/47/01

Fig. 2. *Liosphinctes* cf. *plicatilis* (Sowerby); lower nodular limestones (unit 3B), about 5.05 m above the base; Plicatilis Zone, Middle Oxfordian; ZI/47/03

Fig. 3. *Euaspidoceras paucituberculatum* (Arkell); lower nodular limestones (unit 3B), rubble about 5.05–5.80 m above the base; Plicatilis Zone – lower part of Transversarium Zone, Middle Oxfordian; ZI/47/04

Fig. 4. *Gregoryceras* (*Gregoryceras*) sp.; lower nodular limestones (unit 3B), 5.57 m above the base; Middle Oxfordian or lowermost part of Upper Oxfordian; ZI/47/05

Fig. 5. *Perisphinctes* (*Dichotomoceras*) cf. *bifurcatus* (Quenstedt); lower nodular limestones (unit 3B), rubble; Bifurcatus Zone, Upper Oxfordian; ZI/47/06

Fig. 6. *Sowerbyceras tortisulcatum* (d'Orbigny); lower nodular limestones (unit 3B), 5.27 m above the base, Plicatilis Zone, Middle Oxfordian; ZI/4707

Fig. 7. *Presimoceras* cf. *teres* (Neumayr); upper nodular limestones (unit 3D), at the base; Divisum/Herbichi Zone, Lower Kimmeridgian; ZI/4710

Fig. 8. *Nebrodites peltoideus* (Gemmelaro), upper nodular limestones (unit 3D), lowermost part, rubble; Divisum/Herbichi Zone, Lower Kimmeridgian; ZI/47/11

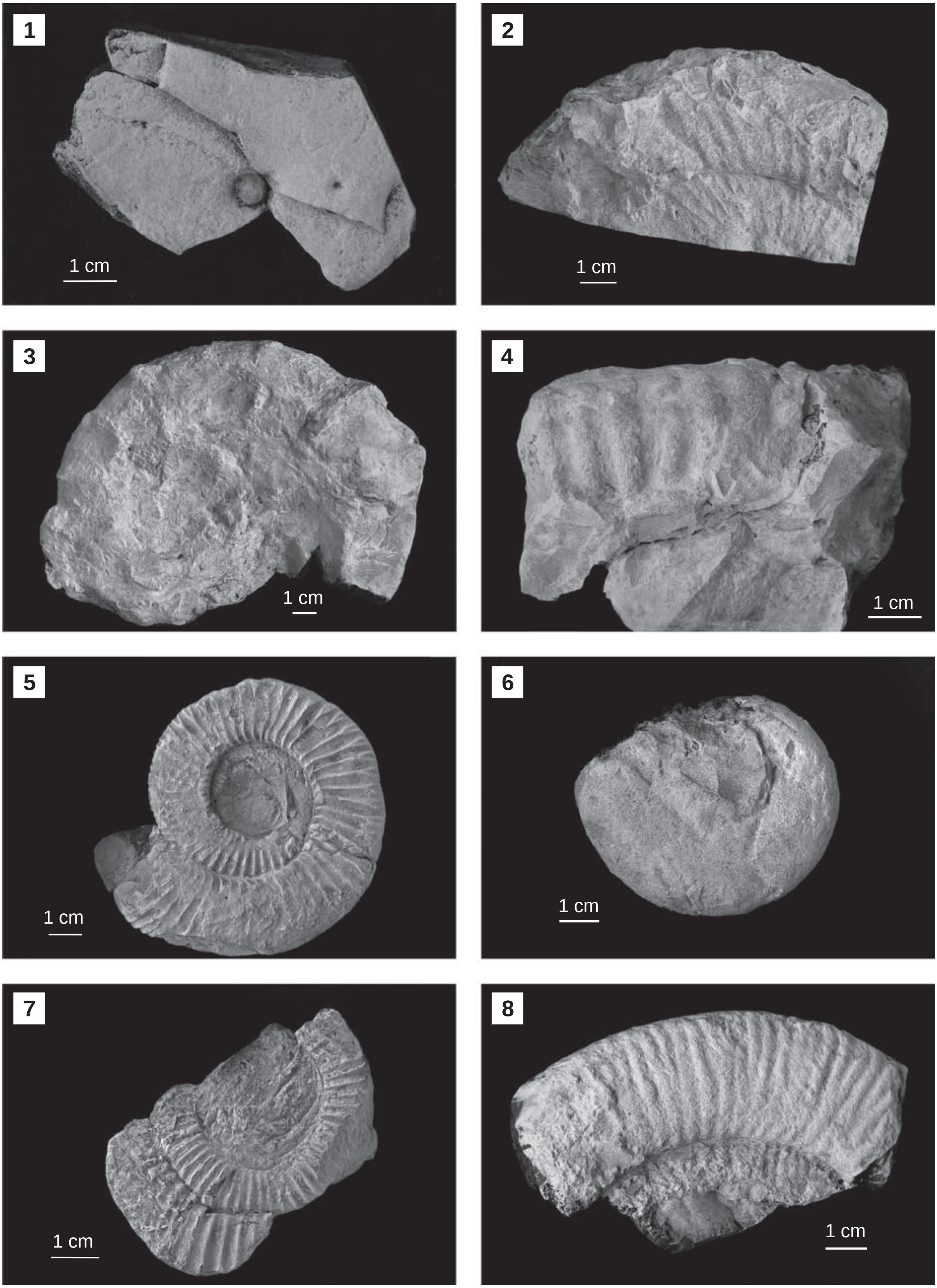
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PLATE 7

Upper Kimmeridgian ammonites

Fig. 1. *Taramelliceras* (*Taramelliceras*) *pugile pugiloide* (Canavari); upper nodular limestones (unit 3D), about 0.5 m above the base; Acanthicum Zone, Upper Kimmeridgian; ZI/47/12

Figs 2, 3. *Progeronia* ex gr. *eggeri* (Ammon) – *breviceps* (Quenstedt), upper nodular limestones (unit 3D), about 0.70–0.75 m above the base; Acanthicum Zone, Upper Kimmeridgian; ZI/47/13 and ZI/47/14

Fig. 4. *Lytoceras polycyclum* Neumayr/*Lytoceras polycyclum camertinum* Canavari; upper nodular limestones (unit 3D), about 0.7 m above the base; Acanthicum Zone, Upper Kimmeridgian; ZI/47/15

Fig. 5. *Sowerbyceras loryi* (Munier Chalmas *in* Pillet & de Fromental, 1875); upper nodular limestones (unit 3D), 0.75 m above the base; Acanthicum Zone, Upper Kimmeridgian; ZI/47/16

Fig. 6. *Hemihaploceras* sp.; upper nodular limestones (unit 3D), about 0.75 m above the base; Cavouri Zone, Upper Kimmeridgian; ZI/47/17

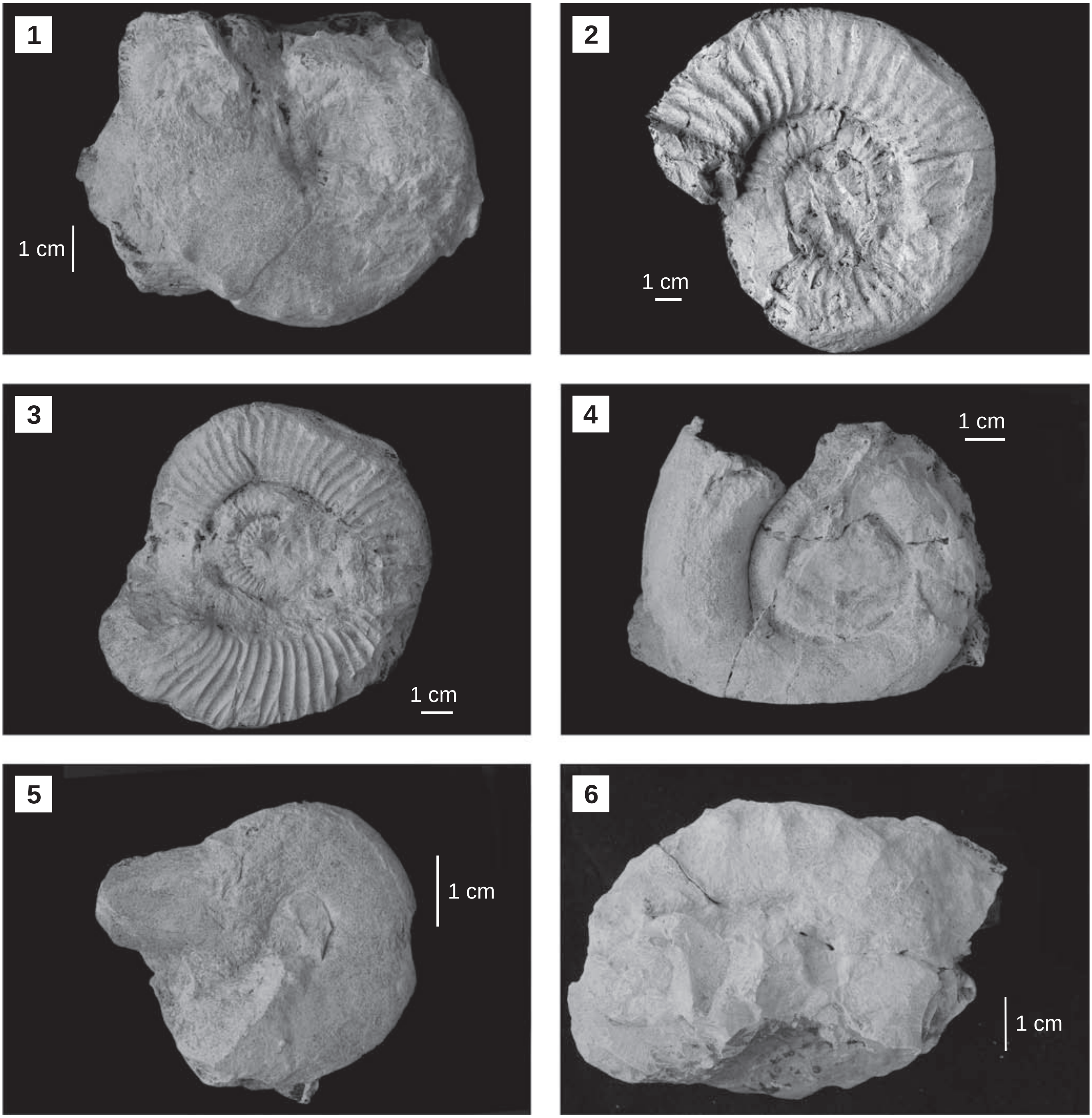
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PLATE 8

Tithonian and Berriasian calpionellids

Fig. 1. *Chitinoidella boneti* Doben; upper nodular limestones (unit 3D); sample 35; Boneti Subzone, Chitinoidella Zone, Upper Tithonian

Fig. 2. *Praetintinnopsella andrusovi* Borza; upper nodular limestones (unit 3D); sample 37; Praetintinnopsella Zone, Upper Tithonian

Fig. 3. *Crassicollaria massutiniana* (Colom); pink pelitic limestones (unit 3E); sample 40; Crassicollaria Zone, Upper Tithonian

Fig. 4. *Crassicollaria parvula* Remane; pink pelitic limestones (unit 3E); sample 40; Crassicollaria Zone, Upper Tithonian

Fig. 5. *Calpionella alpina* Lorenz; pink pelitic limestones (unit 3E); sample 49; Ferasini Subzone, Calpionella Zone, Lower Berriasian

Fig. 6. *Remaniella colomi* Pop; biogenic limestones alternating with volcanogenic rocks (unit 5); sample 57; Simplex Subzone, Calpionellopsis Zone, Upper Berriasian

Fig. 7. *Remaniella ferasini* (Catalano); pink pelitic limestones (unit 3E); sample 51; Ferasini Subzone, Calpionella Zone, Lower Berriasian

Fig. 8. *Remaniella catalanoi* Pop; micritic limestones (unit 3E); sample 51; Ferasini Subzone, Calpionella Zone, Middle Berriasian

Fig. 9. *Remaniella filipescui* Pop; breccia limestones (unit 6); sample 59; Oblonga Subzone, Calpionellopsis Zone, Upper Berriasian

Fig. 10. *Lorenziella hungarica* Knauer; pink pelitic limestones (unit 3E), uppermost part; sample 54; Elliptica Subzone, Calpionella Zone, Middle Berriasian

Fig. 11. *Calpionellopsis simplex* (Colom); biogenic limestones alternating with volcanogenic rocks (unit 5); sample 57; Simplex Subzone, Calpionellopsis Zone, Upper Berriasian

Fig. 12. *Calpionellopsis oblonga* (Cadisch); breccia limestones (unit 6); sample 58; Oblonga subzone, Calpionellopsis Zone, Upper Berriasian

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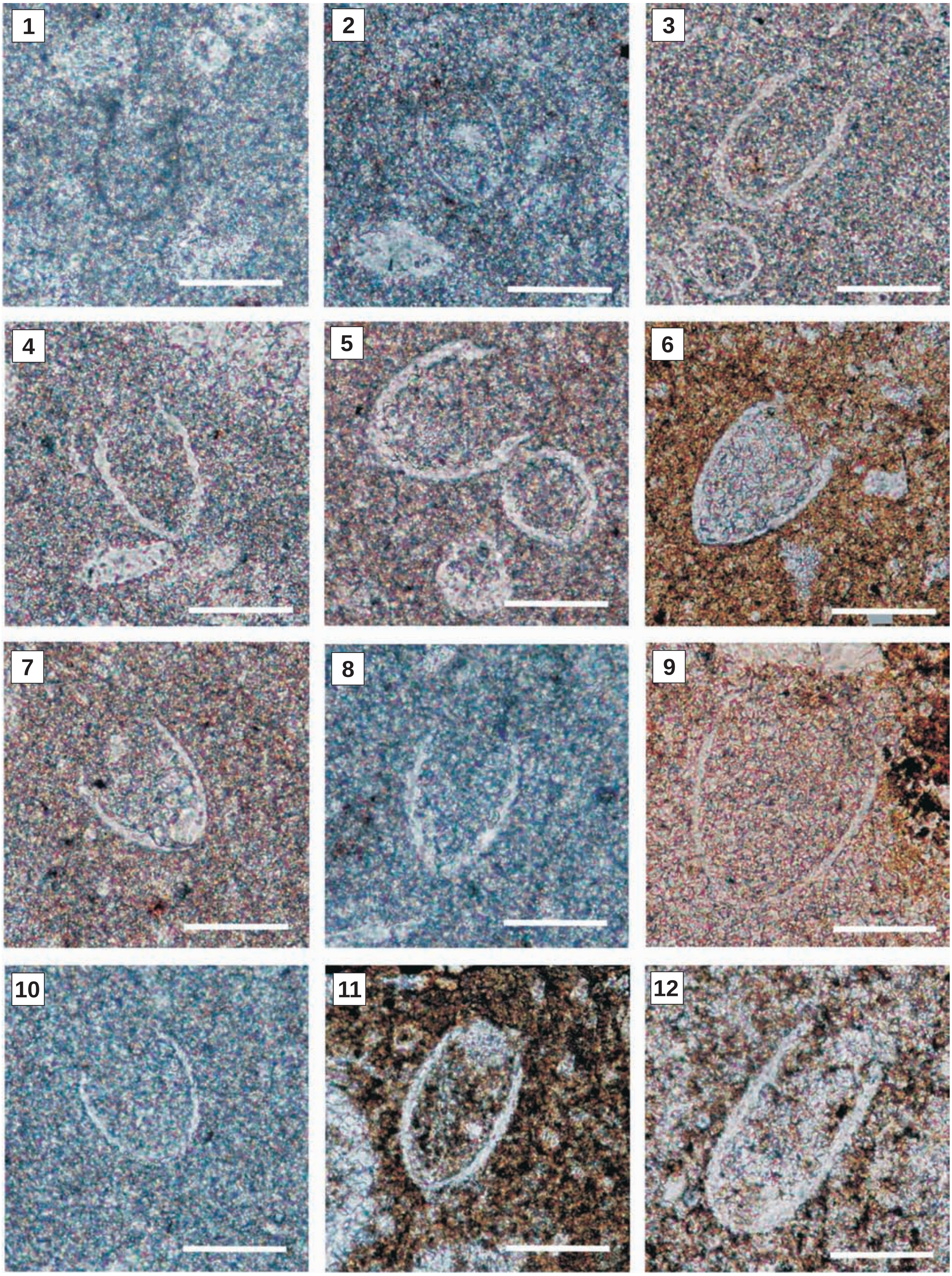

Daniela REHÁKOVÁ *et al.* — Stratigraphy and microfacies of the Jurassic and lowermost Cretaceous of the Veliky Kamenets section...

PLATE 9

Upper Jurassic to lowermost Cretecous calcareous dinocysts

Fig. 1. *Cadosina parvula* Nagy; cherty limestones (unit 3C); sample 22; Parvula Acme Zone, Lower Kimmeridgian

Fig. 2. *Colomisphaera fibrata* (Nagy); cherty limestones (unit 3C), base; sample 14; Upper Oxfordian

Fig. 3. *Colomisphaera pieniniensis* (Borza); cherty limestones (unit 3C); sample 20; Parvula Acme Zone, Lower Kimmeridgian

Fig. 4. *Schizosphaerella minutissima* (Colom); upper nodular limestones (unit 3D); sample 34; Semiradiata Zone, Lower Tithonian

Fig. 5. *Colomisphaera carpathica* (Borza); upper nodular limestones (unit 3D); sample 28; Tithonica Zone, Lower Tithonian

Figs 6, 7. *Colomisphaera nagyi* (Borza); cherty limestones (unit 3C); sample 20; Parvula Acme Zone, Lower Kimmeridgian

Fig. 8. *Colomisphaera radiata* (Vogler); cherty limestones (unit 3C); sample 15; Fibrata Acme Zone, Upper Oxfordian/Lower Kimmeridgian

Fig. 9. *Stomiosphaera moluccana* Wanner; upper nodular limestones (unit 3D), base; sample 23; Moluccana Zone, Upper Kimmeridgian

Fig. 10. *Carpistomiosphaera borzai* (Nagy); upper nodular limestones (unit 3D); sample 26; Borzai Zone, Upper Kimmeridgian

Figs 11, 12. *Colomisphaera pulla* (Borza); upper nodular limestones (unit 3D); sample 27; Pulla Acme Zone, lowermost Tithonian

Fig. 13. *Carpistomiosphaera tithonica* Nowak; upper nodular limestones (unit 3D); sample 29; Tithonica Zone, Lower Tithonian

Fig. 14. *Parastomiosphaera malmica* (Borza); upper nodular limestones (unit 3D); sample 32; Malmica Zone, Lower Tithonian

Fig. 15. *Cadosina semiradiata fusca* Wanner; breccia limestones (unit 6); sample 58; Oblonga Subzone, Calpionellopsis Zone, Upper Berriasian

Fig. 16. *Cadosina semiradiata semiradiata* Wanner; upper nodular limestones (unit 3D); sample 32; Malmica Zone, Lower Tithonian

Fig. 17. *Stomiosphaerina proxima* Řehánek; pink pelitic limestones (unit 3E); sample 54; Elliptica Subzone, Calpionella Zone, Middle Berriasian

Fig. 18. *Cadosina minuta* Borza; breccia limestones (unit 6); sample 58; Oblonga Subzone, Calpionellopsis Zone, Upper Berriasian

Fig. 19. *Carpistomiosphaera valanginiana* Borza; breccia limestones (unit 6); sample 59; Oblonga Subzone, Calpionellopsis Zone, Upper Berriasian

Fig. 20. *Colomisphaera vogleri* (Borza); breccia limestones (unit 6); sample 59; Oblonga Subzone, Calpionellopsis Zone, Upper Berriasian

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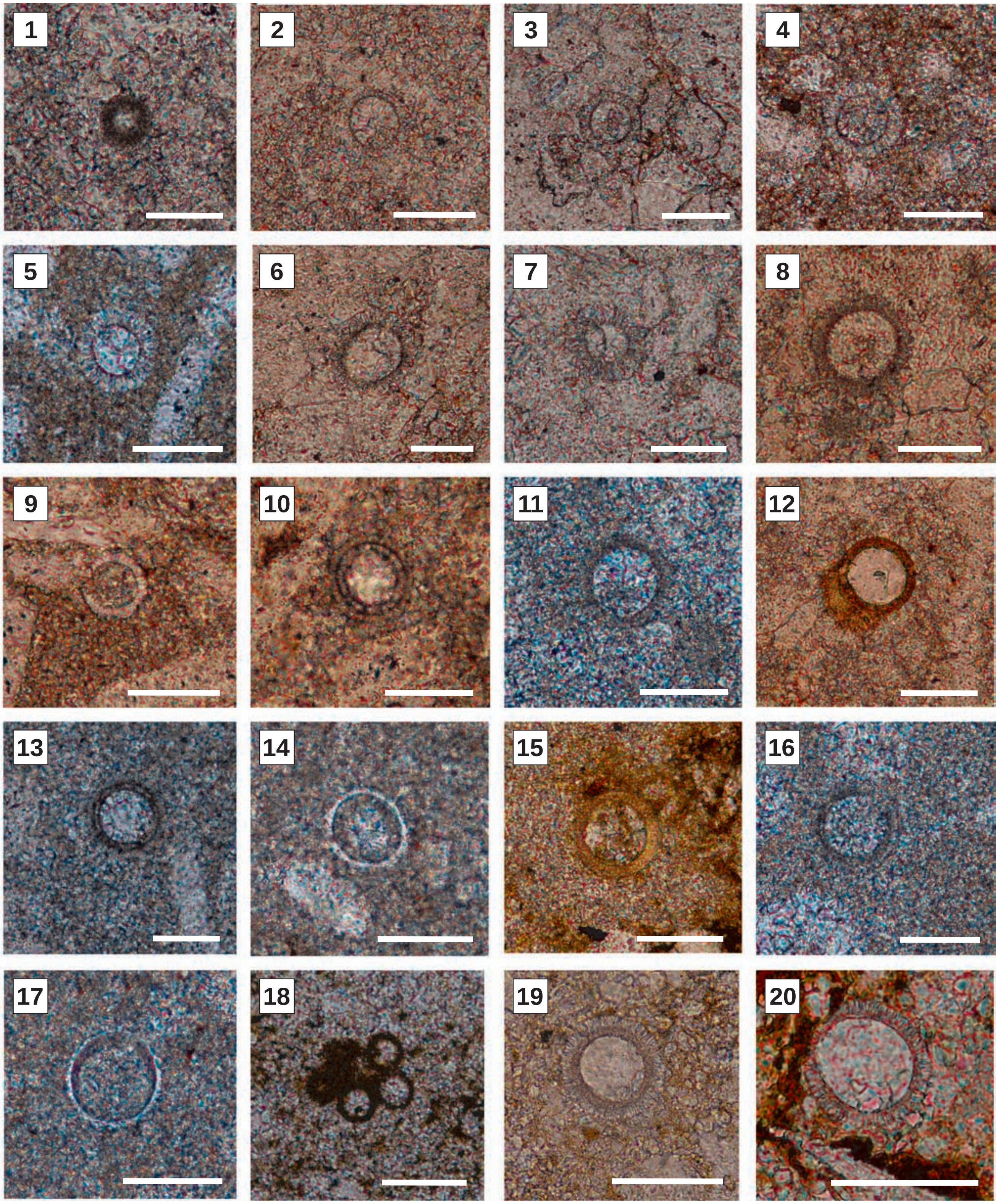
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PLATE 10

Microfacies of Upper Jurassic limestones

Fig. 1. Abundant planktonic foraminifers of *Globuligerina* in biomicrite wackestone to packstone; lower nodular limestones (unit 3B); sample 12; Middle Oxfordian

Fig. 2. *Globochaete-Saccocoma* packstone. Fitted fabric of the secundibrachialia and ramuli from the *Saccocoma* arms; cherty limestones (unit 3C); sample 19; Lower Kimmeridgian

Fig. 3. Pelbiomicropseudosparite of radiolarian-cadosinid microfacies; cherty limestones (unit 3C), uppermost part; sample 22; Parvula Acme Zone, Lower Kimmeridgian

Fig. 4. Acme of *Cadosina parvula* Nagy in pelbiomicrosparite limestone; cherty limestones (unit 3C), uppermost part; sample 22; Parvula Acme Zone, Lower Kimmeridgian

Fig. 5. *Globochaete* blooming in *Saccocoma* – *Globochaete* packstone with frequent juvenile ammonites; upper nodular limestones (unit 3D); sample 27; Pulla Acme Zone, lowermost Tithonian

Fig. 6. Packstone of *Globochaete-Saccocoma* microfacies in nodular limestone. Fragments of bivalve shells are leached and secondary filled by calcite aggregates; upper nodular limestones (unit 3D); sample 28; Tithonica Zone, Lower Tithonian

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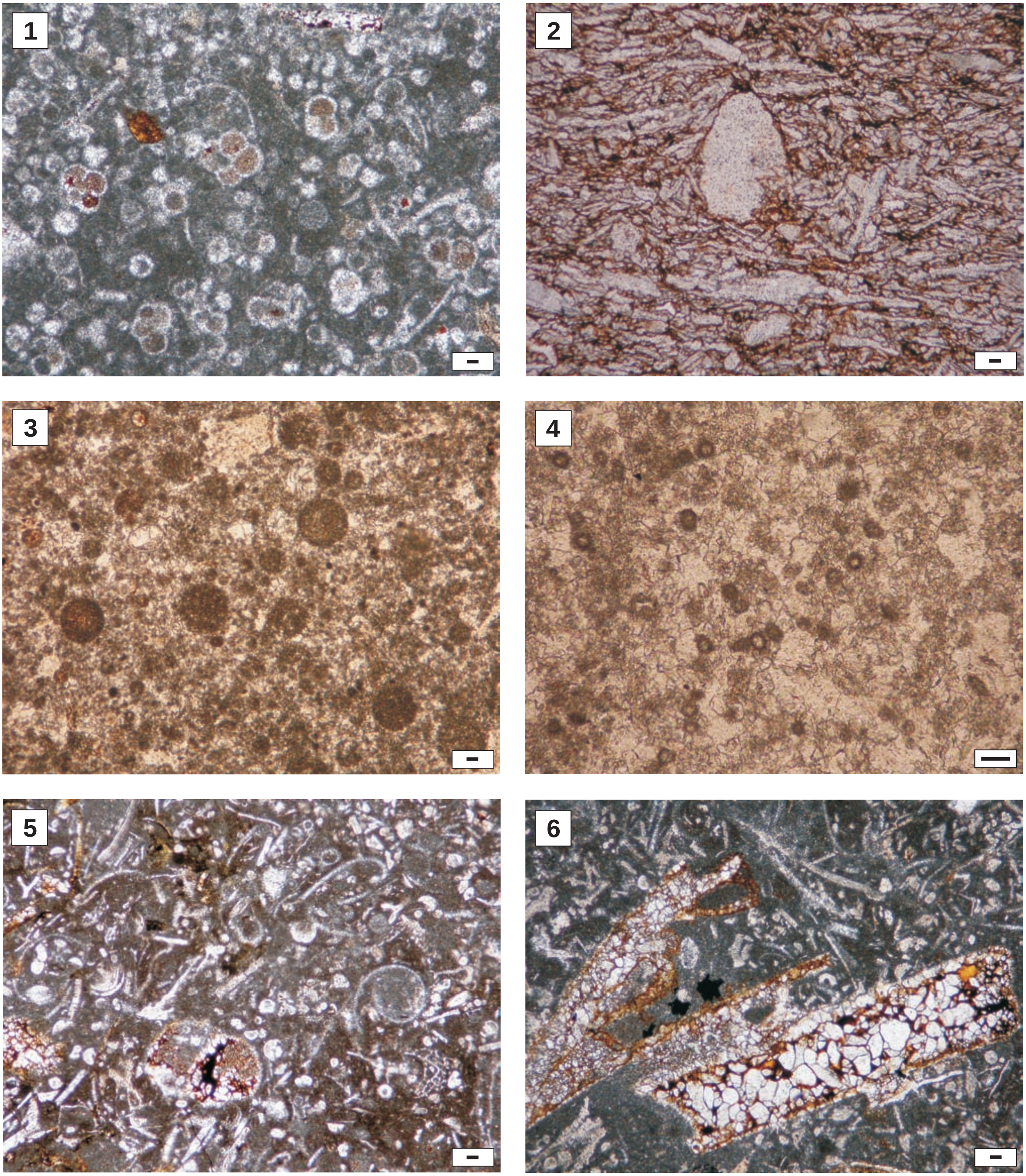
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PLATE 11

Microfacies of Tithonian and Berriasian limestones

Fig. 1. Fragment of agglutinated benthic foraminifera in biomicrite limestone of Crassicollaria Zone; pink micritic limestones (unit 3E); sample 40; Crassicollaria Zone, Upper Tithonian

Fig. 2. Fragment of crinoid calyx in biomicrite wackestone which contains microfossils of the Praetintinnopsella Zone (Upper Tithonian); upper nodular limestones (unit 3D); sample 37

Fig. 3, 4. Bioturbated breccia limestone. Matrix contains intraclasts of two microfacies types (the radiolarian and the calpionellid ones) and microfossils of Ferasini Subzone (Calpionella Zone, Lower Berriasian) – unit 3E); sample 52

Fig. 5. Frequent *Cadosina semiradiata fusca* Wanner in biomicrosparitic limestone; breccia limestones (unit 6); sample 58; Oblonga Subzone, Calpionellopsis Zone, Upper Berriasian

Fig. 6. Intraclasts of biomicrosparite limestone with *Cadosina semiradiata fusca* Wanner among the matrix composed of basaltic volcanite; sample 58; Oblonga Subzone, Calpionellopsis Zone, Upper Berriasian

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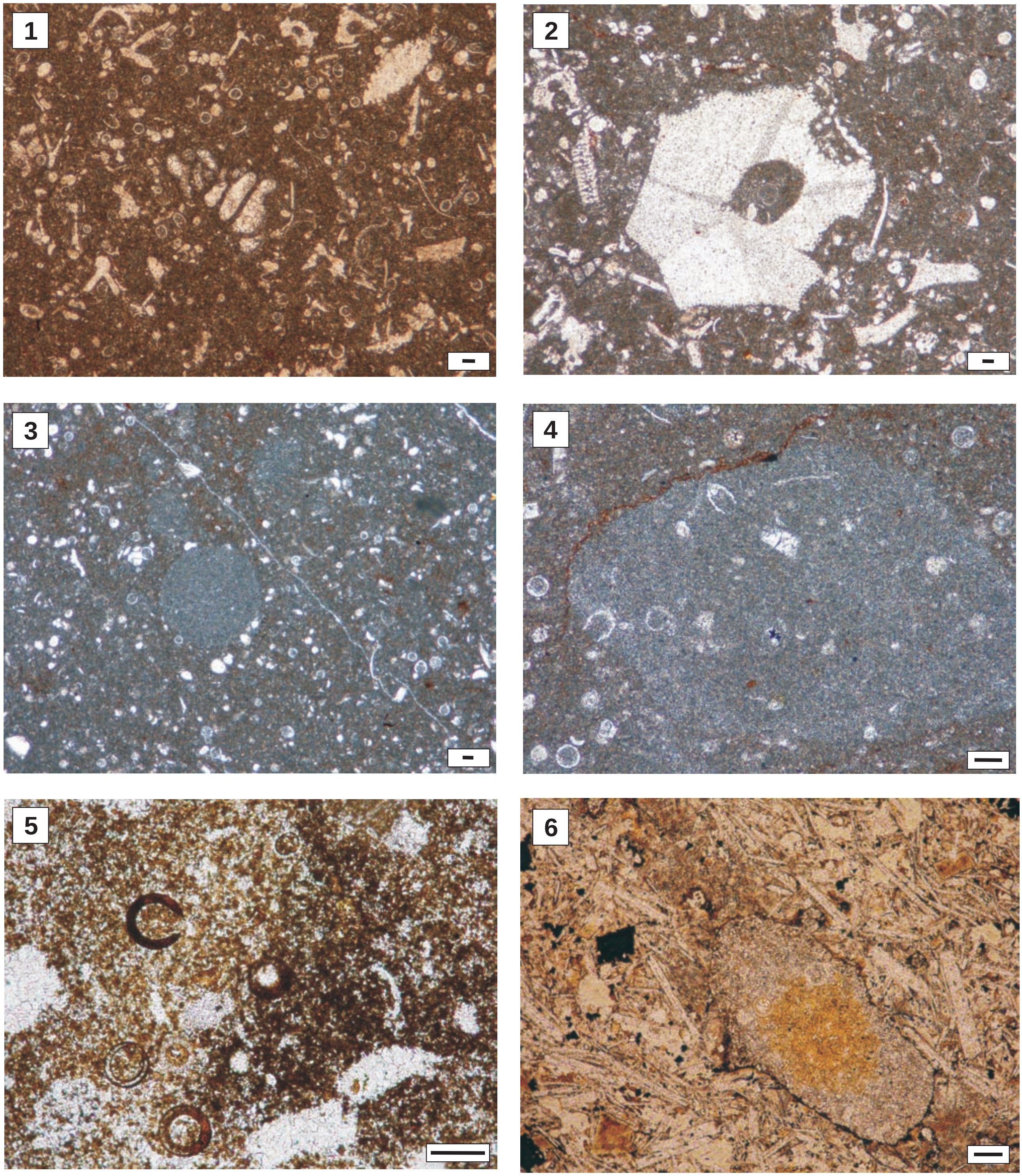
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