The stratigraphy and palaeogeographic position of the Jurassic successions of the Priborzhavske-Perechin Zone in the Pieniny Klippen Belt of the Transcarpathian Ukraine

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Abstract. The Jurassic deposits which crop out in the quarries at Priborzhavske, Perechin and Novoselitsa in the Transcarpathian Ukraine comprise fairly similar successions, allowing their interpretation as corresponding to a single palaeogeographic zone in the Pieniny Klippen Basin. To the same zone belong also deposits from Beňatina quarry in eastern Slovakia. The following main stratigraphic units may be recognized: terrigenous and fleckenkalk–fleckenmergel deposits (Sinemurian-Pliensbachian), highly diversified and condensed deposits (uppermost Pliensbachian-Aalenian), crinoidal limestones (Bajocian, with a stratigraphical gap covering a lower part of the Lower Bajocian), nodular limestones of ammonitico-rosso type (uppermost Bajocian to Oxfordian with a possible gap covering the Callovian and Lower Oxfordian), well bedded micritic limestones (Kimmeridgian to Upper Tithonian), and bedded limestones with cherts of the maiolica type (from the uppermost Tithonian). Two rifting phases, well developed in the successions, took place: (1) Devín phase during latest Pliensbachian-Toarcian-and at least earliest Aalenian, and (2) Krasín phase during the Bajocian. The onset of pelagic deposits overlying the rift strata took place during the latest Bajocian, and corresponds well with the general subsidence and development of a more uniform facies pattern during the post-rifting time as everywhere in the Pieniny Klippen Basin. Selected ammonite taxa of the Lower and lower part of the Middle Jurassic are illustrated and discussed.

INTRODUCTION

The Jurassic deposits of the south-eastern part of the Pieniny Klippen Belt in the Transcarpathian Ukraine (Figs 1, 2) crop out in the active quarries at Priborzhavske, as well as in the abandoned quarry at Perechin, previously described by Kruglov (1971) and Slavin (1972). In addition a small active quarry close to Perechin, at Novoselitsa, shows a marked similarity in its sedimentary development. Similar Jurassic deposits are known also from Beňatina quarry in easternmost Slovakia (Schlőgl *et al.*, 2004; see also Krobicki *et al.*, 2003). All these localities form a well defined palaeogeographic zone, and the deposits occurring there differ markedly both in their facies development and stratigraphical position from the coeval Jurassic deposits in other areas of the Pieniny Klippen Belt – in eastern Slovakia and Poland. The present authors decided to undertake this study to complete the general knowledge of the stratigraphy and palaeogeography of the Jurassic deposits in the Ukrainian section of the Pieniny Klippen Belt (see also Reháková *et al.*, 2011; Krobicki *et al.*, 2012).

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SUCCESSIONS AT PRIBORZHAVSKE

The deposits cropping out in two large quarries at Priborzhavske village, about 16 kilometres E of the Irshava town (Fig. 2) were studied by the present authors in 1999–2000. The deposits, mostly in an overturned position, occur in two tectonic units which overthrust each other (Figs 3, 4): a lower tectonic unit exposed in the south-western part of the quarries and showing deposits from the lowermost part of the Lower Jurassic up to the Upper Jurassic (and Upper Cretaceous), and an upper tectonic unit exposed in the north-eastern part of the quarries and showing deposits from the Middle Jurassic up to Lower Cretaceous (Figs 5, 6). Each of the tectonic units shows a somewhat different succession of deposits, and thus they represent somewhat different facies zones. For this reason the particular lithostratigraphic units described below are denoted not only by the following Roman numbers, but also by a letter A or B indicating the affilation of the deposits to the given tectonic unit (A – lower tectonic unit; B – upper tectonic unit) – Fig. 4.

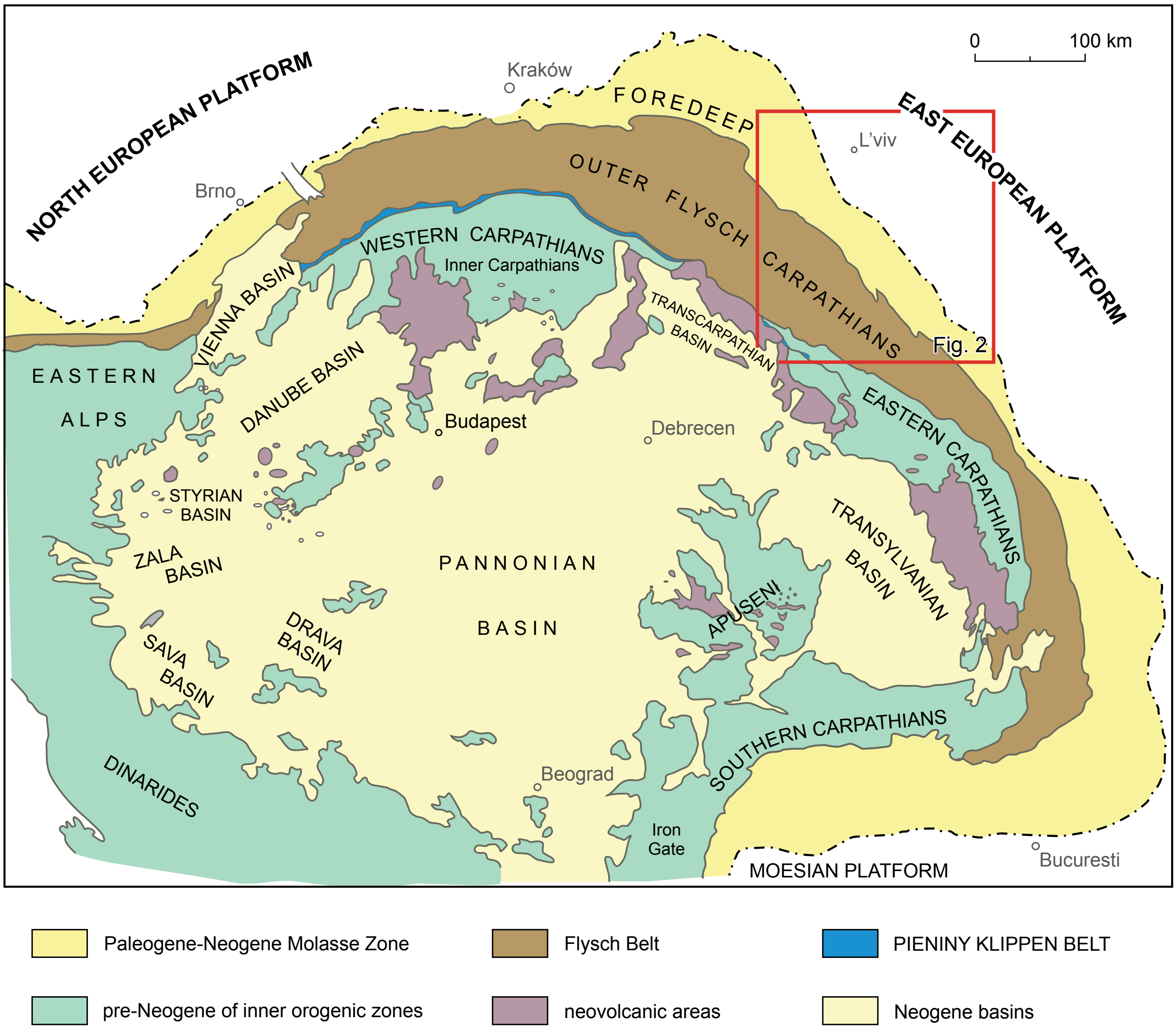

Fig. 1. Tectonic sketch map of the Alpine-Carpathian-Pannonian-Dinaride region showing the position of the area of study (after Kováč *et al.*, 1998; Plašienka *et al.*, 2000; modified)

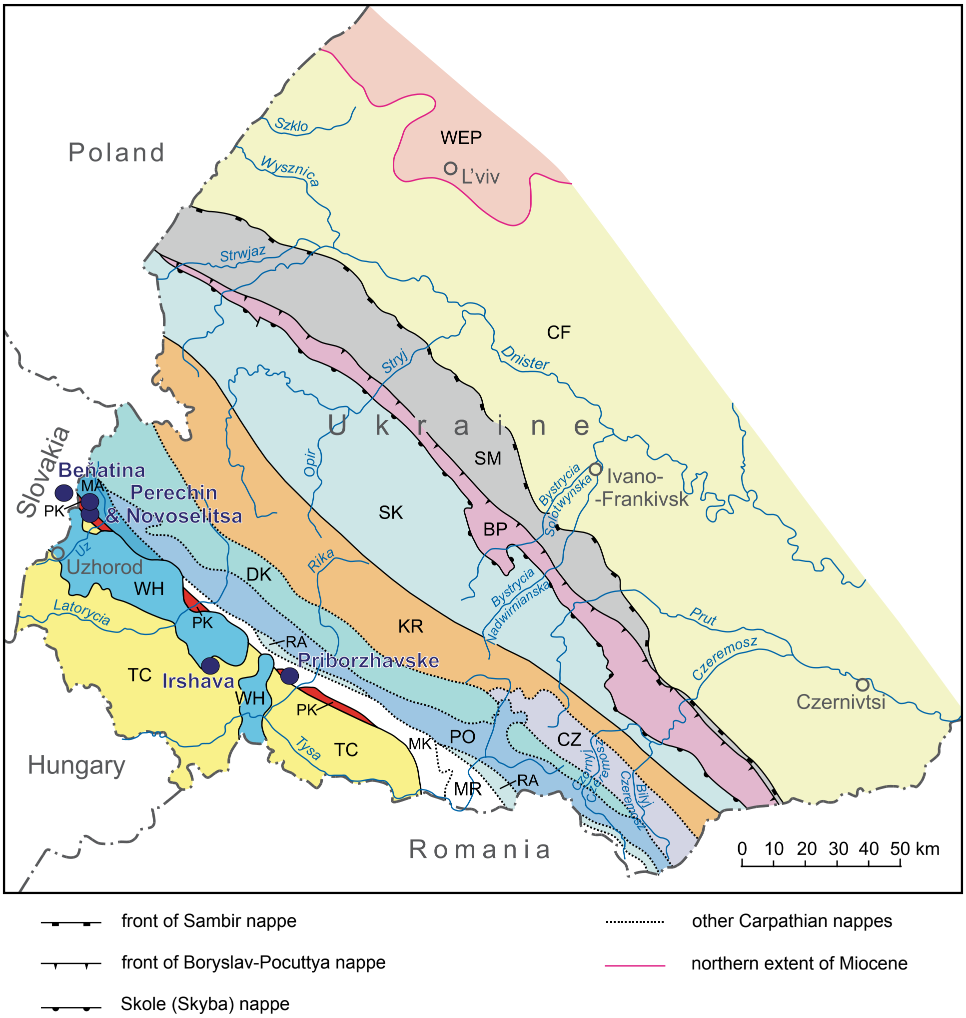

Fig. 2. Ukrainian Carpathians tectonic map (after Glushko, Kruglov, 1986; modified and simplified) showing the position of the sections studied in the Pieniny Klippen Belt (in red)

Abbreviations: WEP – West European platform; CF – Carpathian foredeep; SM – Sambir nappe; BP – Boryslav-Pokuttya nappe; SK – Skyba nappe; KR – Krosno zone; CZ – Chornohora nappe; DK – Dukla nappe; PO – Porkulec nappe; RA – Rahiv nappe; MA – Magura nappe; MR – Marmarosh massif; MK – Marmarosh Klippen zone; PK – Pieniny Klippen Belt; TC – Transcarpathian depression; WH – Vihorlat-Hutyn volcanic chain

LOWER TECTONIC UNIT (A)

Lithology and lithostratigraphy (Figs 5 and 7–9)

The oldest deposits (AI) are blue-gray marls and marly shales with intercalations of crinoidal limestones. Sometimes, a richer fauna represented by oysters (*Gryphea*) and spiriferinids is encountered at the top of limestone beds. The exposed part of unit AI is 6.25 m thick.

The directly overlying unit (AII) is composed of siltstones and fine-grained sandstones with common flakes of muscovite; thin (up to few centimetres in thickness) intercalations of limestones with laminae containing detrital material are occasionally seen. The presence of pyroclastic material composed mostly of sharp-edged quartz fragments of different shapes (triangles, blades, needles) is recognized in thin-section in the laminae. The total thickness of the unit is 3.75 m.

The very characteristic younger unit (AIII) of the fleckenkalk–fleckenmergel facies consists of spotted, well bedded limestones and marly limestones intercalated by marls. The lowermost part of the unit, about 1 m in thickness,

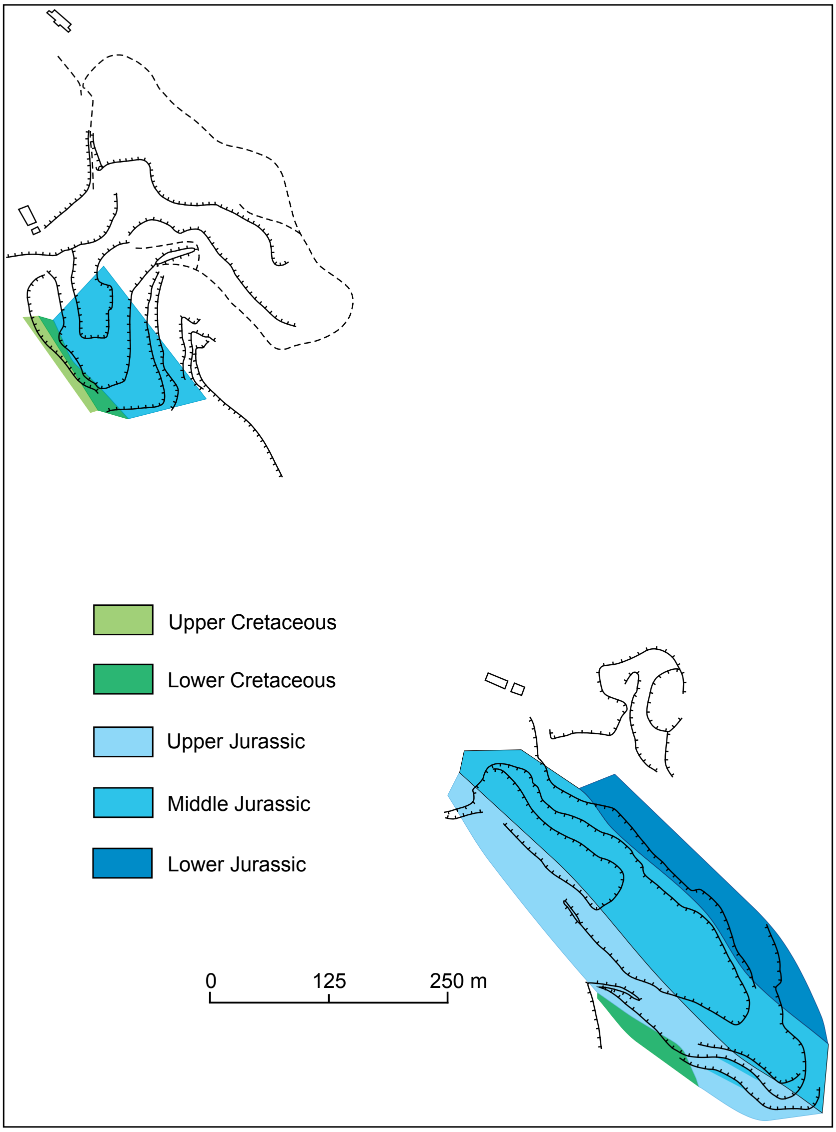

Fig. 3. Geological sketch map showing distribution of the Jurassic and Cretaceous deposits of the lower tectonic unit (A – see text) in the quarries at Priborzhavske (after Krobicki *et al.*, 2012)

is represented by limestone beds (0.25–0.50 m in thickness) with subordinate intercalations of dark marl – the deposits contain numerous bioclasts, oysters (*Gryphea*) and burrows of *Chondrites*; the thickness of particular limestone beds in the lower and middle parts of the unit oscillates between 0.1 m and 0.25 m, whereas the marls in between are either of similar thickness, or even attain from 0.30–0.45 m in thickness. The lower and middle parts of the unit attain about 9 metres in thickness – and they consist of: about 4.6 m thick exposed interval in the lower part, about 2 metres of non-exposed deposits, and about 2.5 m thick interval of the middle part. The thickness of the limestone beds ranges from 7 to 50 centimetres, whereas that of the marls – from 2 to 47 centimetres. Still higher, there occur limestones, marly limestones and marls in beds from 0.05 m up to 0.2 m thick – these deposits are about 2.25 m in thickness (with a non-exposed interval below which is about 1.10 m thick). Ammonites are common in the middle part of the unit (8.5–10.0 m from its base) and in the upper part of the unit. The uppermost part of unit AIII, about 3.5 m in thickness, consists of marls (in beds from 0.1 to 0.45 m in thickness) with intercalations of limestones (0.1 m to 0.2–0.3 m in thickness) which show a somewhat nodular character. The total thickness of unit AIII is about 16.5 m.

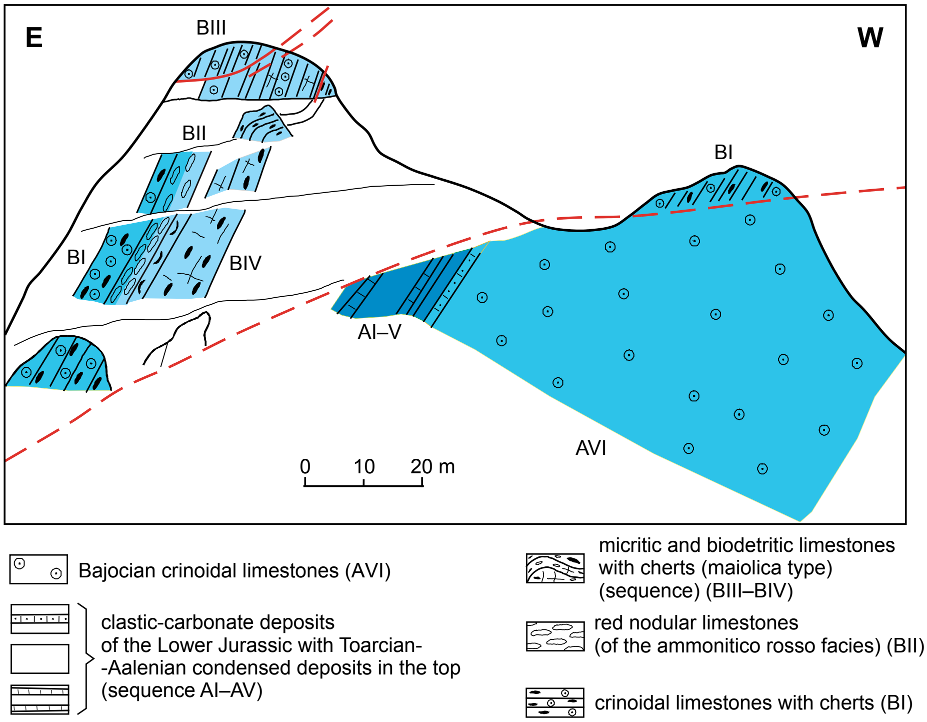

Fig. 4. Geological sketch section showing the relative position of two tectonic units/successions in the southern quarry at Priborzhavske (after Krobicki *et al.*, 2012)

Unit AIV is developed as greenish, less commonly pink--greenish or spotted greenish-cherry sandy marls (beds 0.2–0.4 m in thickness) with intercalations of sandy limestones (0.1–0.2 m in thickness); upwards there appear sandy crinoidal limestones with marly intercalations – the thickness of the limestone and marl beds is similar and equals 0.15–0.30 m. More thick beds of sandy, sometimes crinoidal, limestone (up to 0.5 m in thickness) locally with the admixture of quartz gravels occur in the upper part of the unit in question; there appear also silty marls. Glauconite grains are found commonly; belemnite rostra are often encountered (Fig. 8). The total thickness of unit AIV is generally small, but variable, and it oscillates from 1.85 m up to 2.90 m.

Unit AV shows a very small thickness from several centimetres up to 0.25 m, and it consists of very diversified deposits. Sometimes, the deposits of the unit are completely missing – and the only trace of the unit is a thin ferrugineous crust at the top of unit AIV.

In particular sections the deposits of unit AV are developed: either as (1) rusty-reddish and brownish limestones with ferrugineous ooids and stromatolitic encrustations, and large (up to 10 cm in diameter) oncoids; shells of ammonites (*Harpoceras* and *Hildoceras*), belemnite rostra, and large quartz grains are normally encountered in the deposits; and/or as (2) ammonite pavements (ammonites: *Staufenia*, *Ludwigia*, *Brasilia*, *Graphoceras*, lytoceratids and phylloceratids) with quartz gravel, belemnite rostra, brachiopod and gastropod shells and fish teeth (see Kalinichenko *et al.*, 1965 a, b; Kalinichenko, Kruglov, 1971). Thin subhorizontal neptunian dykes ranging down into the sandy crinoidal limestones of unit AIV, and filled with white laminated micritic limestones, should also be correlated with unit AV; in one of such dykes has been found an ammonite of the Leioceratinae (*Leioceras* sp.). Belemnites from unit AV were described by Kruglov and Krymholz (1966) and Gavrilishin and Kruglov (1972). It should be remembered, however, that locally coeval deposits show a more expanded character: an about 8 m thick subunit, composed of greenish and variegated clays and gray shales, marls and limestones with ammonites of the genus *Ludwigia*, was described from Priborzhavske quarry (Kruglov, 1971; Kalinichenko, Kruglov, 1971).

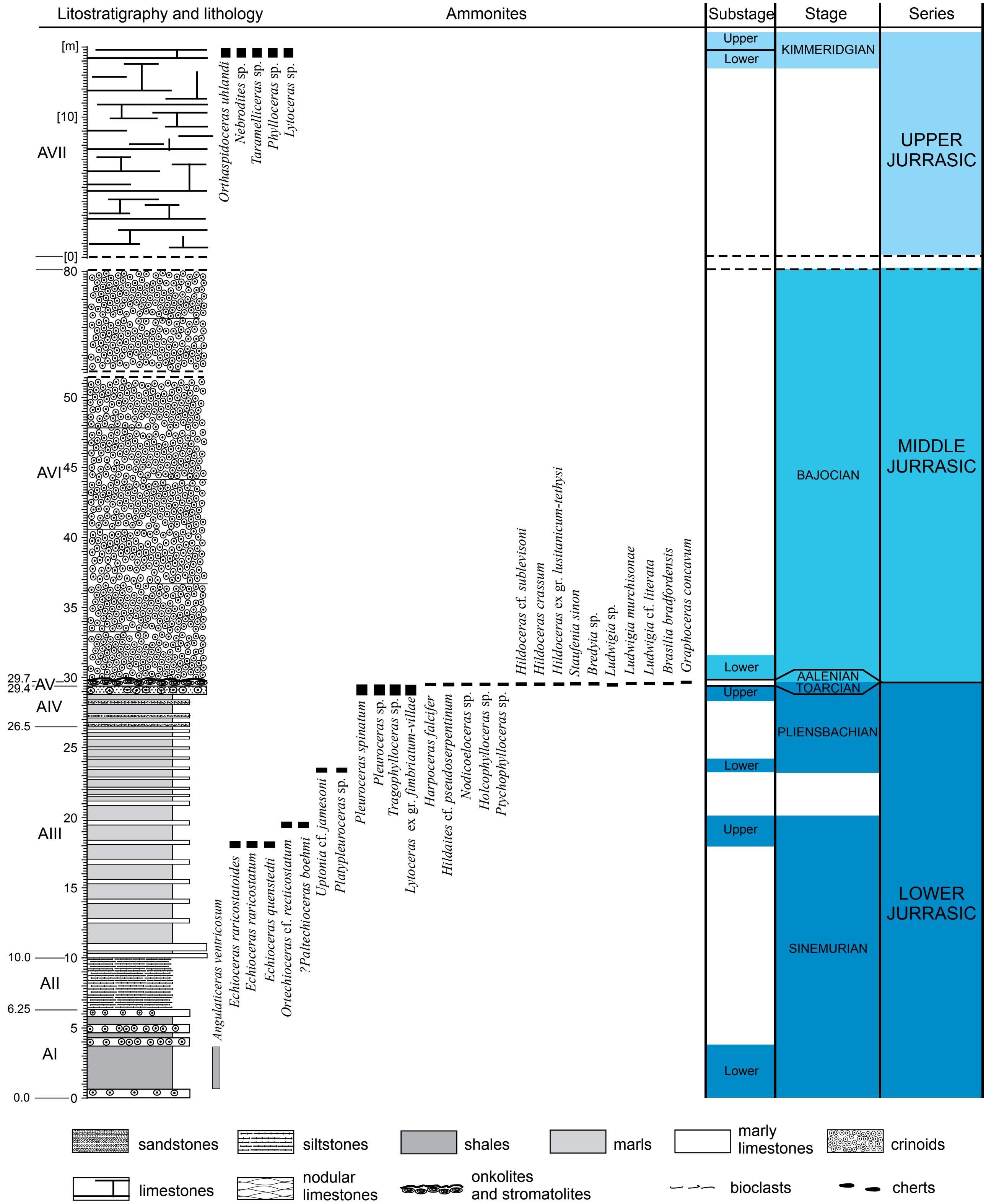

Fig. 5. Succession of Jurassic deposits of the lower tectonic unit (A) in the Priborzhavske quarries and their chronostratigraphical interpretation

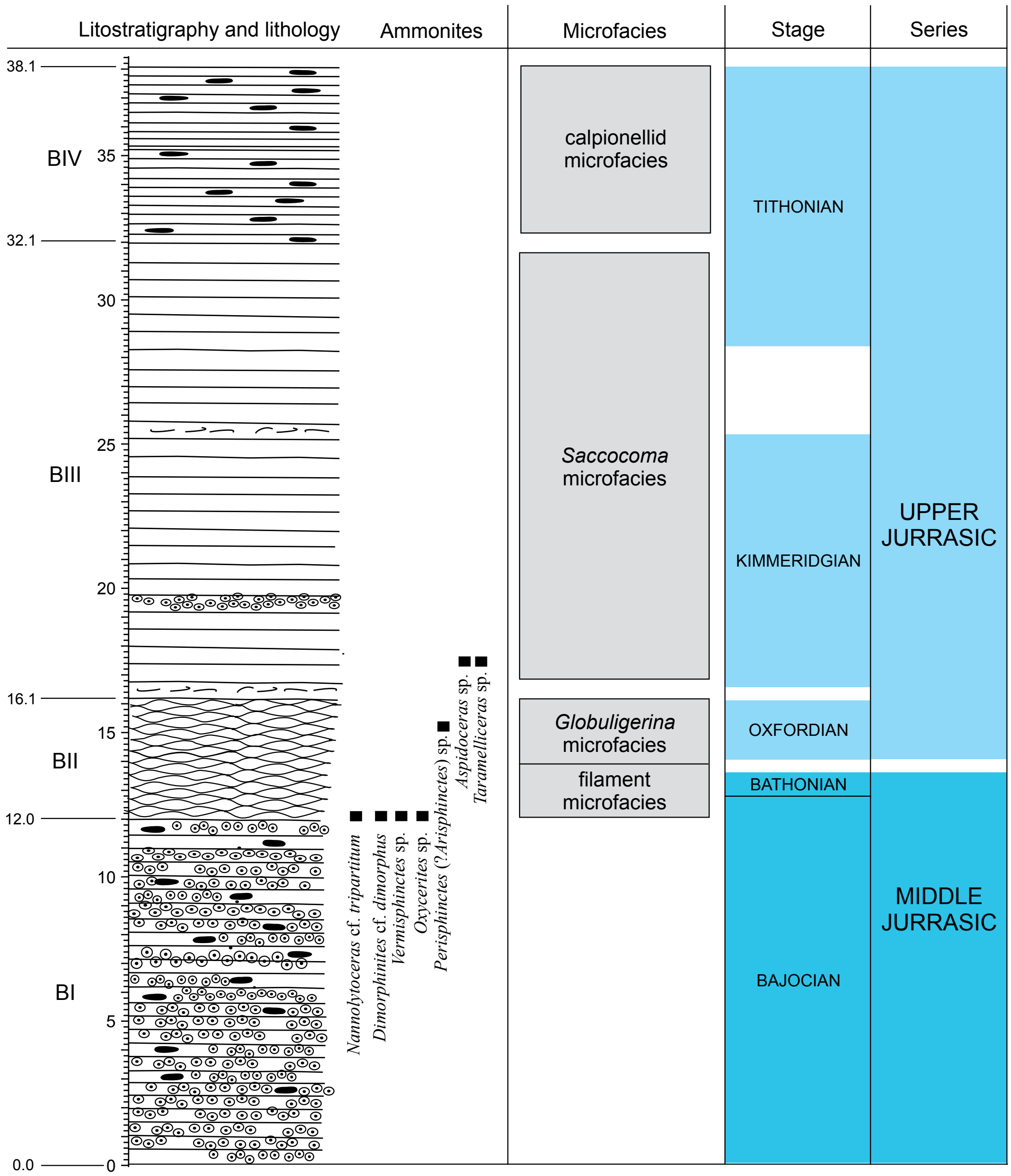

Fig. 6. The succession of the Jurassic deposits of the upper tectonic unit (B) in the Priborzhavske quarries and their chronostratigraphical and microfacies interpretation

Explanations in Fig. 5

Younger deposits (unit AVI), being the main object of exploitation in the quarries, are massive and thick bedded crinoidal limestones several tens of metres in thickness. These are gray, gray-greenish, or pinkish grainstones containing beside crinoid fragments, brachiopod shells, which may be locally abundant. Stromatactis mud-mounds have been recognized in some parts of the succession (Aubrecht *et al.*, 2009). Clasts of greenish micritic limestones a few centimetres in diameter, as well as quartz gravel, are encountered in the lowermost part of the unit. Neptunian dykes up to 0.25 m in thickness filled with micritic limestones containing crinoid ossicles and small gastropods, cut the crinoidal limestones in the lower part of the unit.

Fig. 7. General view of the SE part of the Priborzhavske quarries showing the deposits of the lower tectonic unit (A) exposed in the south-western part

The youngest Jurassic deposits in the south-western part of the southern quarry are developed as well-bedded micritic limestones (unit AVII). These deposits are in tectonic contact with the crinoidal limestones of unit AVI. A greenish limestone packet several tens of centimetres thick, crowded with ammonite shells, occurs in the upper part of unit AVII.

Fig. 8. Glauconitic crinoidal limestones with abundant belemnite rostra of unit AIV (uppermost Pliensbachian) at Priborzhavske

Biostratigraphy and chronostratigraphy

The oldest ammonite, *Angulaticeras* (*Sulciferites*) *ventricosum* (Sowerby)[1] (Pl. 1: 1) coming from unit AI, has been found in marl in the quarry rubble. The stratigraphical range of the species is not well known, but generally its occurrence indicates the Lower Sinemurian (mostly the Bucklandi Zone), but possibly it ranges higher into the Obtusum Zone – the lowermost zone of the Upper Sinemurian (see *e.g*. Bloos, 1979; Meister *et al*., 2010; *cf*. also Corna *et al*., 1997).

Ammonites of the genus *Echioceras*[2] occur in the middle part of unit AIII (8.0–8.4 m from its base): these are represented by the commonly occurring *Echioceras raricostatoides* (Vadasz) (Pl. 1: 2–5), and closely related *Echioceras raricostatum* (Zieten) (Pl. 1: 6), as well as by *Echioceras quenstedti* (Schafhäutl) (Pl. 1: 7–9). The specimens of the latter species have been found in a marly bed possibly immediately below the first limestone bed which yielded the representatives of the first two species. The occurrence of the genus *Echioceras* is indicative of the middle part of the Raricostatum Zone, *i.e.* the Raricostatum Subzone of the Upper Sinemurian, and two ammonite horizons are distinguished in the lower part of the Zone: the *rhodanicum* = *quenstedti* horizon below, and the *raricostatum* = *raricostatoides* horizon

[1] Superscript members refer to the descriptions of these specimens in the chapter "Comments on the ammonites" below (page 37)

above (see *e.g.* Corna *et al.*, 1997; Blau, 1998; Page, 2009). Still higher, in the middle part of unit AIII about 9.5 m above its base has been discovered assemblage of poorly preserved ammonites which are referred to as *Ortechioceras* cf. *recticostatum* Trueman et Williams[3] (Pl. 1: 11) and *Paltechioceras* [?*P. boehmi* (Hug)][4] (Pl. 1: 10). If these interpretations are correct – the assemblage may indicate the presence of both the *raricostatum* = *raricostatoides* horizon, and possibly the overlying *boehmi* horizon of the Raricostatum Subzone of the Raricostatum Zone of the Upper Sinemurian (see *e.g.* Schlatter, 1991; Corna *et al.*, 1997; Blau, 1998). The occurrence of these deposits of the Raricostatum Subzone in such a small thickness of beds containing abundant ammonites (Fig. 9) suggests some stratigraphical condensation. The ammonites referred to the genus *Androgynoceras* by Kalinichenko and Kruglov (1969, pl. 2: 3, 4a–б–в) are representatives of *Echioceras* close to *Echioceras raricostatoides* (Vadasz) (see notes on ammonites), and thus they have to be interpreted as indicative of the Raricostatum Subzone of the Upper Sinemurian, and not the Davoei Zone of the Lower Pliensbachian (*op. cit.*). Another ammonite described from Priborzhavske quarry was referred to as *Eoderoceras armatum* (Sowerby) by Hotsanyuk and Leschukch (2006, pl. 2–4) and it seems very close to representatives of this species as interpreted by Blau (1998, p. 225–226, with given synonymy); the occurrence of this species may indicate a somewhat higher part of the Raricostatum Zone than that discussed above, *i.e.* the uppermost part of the Raricostatum Subzone or the Macdonnelli Subzone (see Corna *et al.*, 1997; Blau, 1998).

A still younger ammonite assemblage comes from upper part of unit AIII, about 3.1–3.6 m below the top of the unit, and it consists of numerous ammonites of the genus *Uptonia* referred to as *Uptonia* cf. *jamesoni* (Sowerby)[5] (Pl. 2: 1, 2), and a single specimen referred with reservation to the genus *Platypleuroceras*[6]. The occurrence of these ammonites is indicative of the Jamesoni Subzone of the Jamesoni Zone of the Lower Pliensbachian (see *e.g.* Dommergues *et al.*, 1997).

At the top of the unit AIV ammonites become numerous. Here were found: *Pleuroceras spinatum* (Bruguière)[7] (Pl. 2: 3), *Pleuroceras* sp., and fairly common phylloceratids and lytoceratids such as *Tragophylloceras* sp., and *Lytoceras* ex gr. *fimbriatum* (Sowerby) – *villae* Meneghini. The occurrence of *P. spinatum* indicates the Spinatum Zone – from the upper part of the Apyrenum Subzone up to the Hawskerense Subzone of the uppermost Pliensbachian (see *e.g.* Dean *et al.*, 1961; Dommergues *et al.*, 1997; Géczy and Meister, 1998).

In the upper part of the rusty-reddish and brownish limestones with ferrugineous ooids topped with stromatolitic encrustations of unit AV, two ammonite faunas have been recognized. The older one consists of the ammonites *Harpoceras falcifer* (Sowerby)[8] (Pl. 3: 5), *Hildaites* cf. *pseudoserpentinum* (Buckman)[9] (Pl. 3: 4), *Nodicoeloceras*, and phylloceratids (*Holcophylloceras* and *Ptychophylloceras*); the younger fauna found at the top of the unit between the stromatolite encrustations is composed of representatives of the genus *Hildoceras*[10]: *Hildoceras* cf. *sublevisoni* Fucini (Pl. 3: 1), *H. crassum* Mitzopoulos (Pl. 3: 3) and *H.* ex gr. *lusitanicum* Meister – *tethysi* Géczy (Pl. 3: 2). The older fauna may be correlated with the upper part of the Serpentinum Zone – the Falcifer (= Falciferum) Subzone, representing the uppermost part of the Lower Toarcian, whereas the younger fauna corresponds to the lower part of the Bifrons Zone – the Sublevisoni Subzone, representing the lowermost part of the Middle Toarcian (see *e.g.* Elmi *et al.*, 1997). The occurrence of the three species of the genus *Hildoceras* in the younger ammonite fauna mentioned above suggests the presence of two successive ammonite horizons in the Sublevisoni Subzone: the *sublevisoni* horizon, and the *lusitanicum*/*tethysi* horizon(s) (see Elmi *et al.*, 1997; Rulleau *et al.*, 2001).

Fig. 9. Slabs with ammonites of the genus *Echioceras* from the Upper Sinemurian deposits of unit AIII at Priborzhavske

A younger fauna consisting of occasional specimens illustrated by Kalinichenko and Kruglov (1971, p. 108, pl. 2: 1) and Leskukch and Hotsanyuk (2002, pl. 2: 2–4) from Priborzhavske quarries, and referred to as *Grammoceras* cf. *saemanni* (Dumortier), and *Grammoceras thouarsense* (d'Orbigny) – *G. saemanni* (Dumortier), indicates the presence of a lower part of the Upper Toarcian (Thouarsense–Dispansum zones). The level from which the specimens were collected in the section is, however, not clear, nor is that of the specimens of the subfamily Leioceratinae[11] illustrated by Kalinichenko and Kruglov (1971, pl. 2: 2–5) and Leskukch and Hotsanyuk (2002, pl. 1: 1a–в). The ammonites of the Leioceratinae, although difficult for unequivocal interpretation, seem to correspond to late representatives of the genus *Leioceras*, such as *L.* (*Cylicoceras*) *uncinatum* (Buckman) and/or *L.* (*Cypholioceras*) *comptum evolutum* Contini (*cf.* Kalinichenko, Kruglov, 1971, pl. 2: 2,4; see also paleontological comments herein), and even to *Ancolioceras*/*Staufenia* (*cf.* Kalinichenko, Kruglov, 1971, pl. 2:3). Whereas the former indicates the Bifidatum Subzone of the Opalinus Zone, representing the upper part of the Lower Aalenian, the latter may indicate even the lowermost part of the Middle Aalenian (see Contini *et al.*, 1997).

A small-sized ammonite and the fragment of a larger one found in the laminated limestones of neptunian dykes cutting through the Toarcian deposits are also representatives of *Leioceras* (Pl. 4: 1)*,* thus indicating the presence of the Opalinus Zone of the Lower Aalenian. From the aforegoing, it may be suggested that the *Grammoceras* ammonites mentioned above, described by Kalinichenko and Kruglov (1971) and Leskukch and Hotsanyuk (2002), came from the red and brownish limestones which yielded also older Toarcian ammonites, whereas the representatives of the Leioceratinae described by these authors, came from the topmost part of unit AV – either from ammonite pavements described below, or from their lateral equivalent – the greenish and variegated clays and gray shales, marls and limestones described from the Priborzhavske quarry by Kruglov (1971; see also Kalinichenko, Kruglov, 1971).

Several ammonite faunas may be recognized in ammonite pavements occurring at the top of unit AV. Here may be recognized four faunal assemblages taking into account the known stratigraphical ranges of the most important species: (1) an assemblage composed of *Staufenia sinon* (Bayle)[12] (Pl. 5: 1), and possibly ammonites of the genera *Bredyia* (Pl. 5: 2), as well as fragmentary preserved representatives of *Ludwigia*; this assemblage is representative of the Haugi Subzone of the Murchisonae Zone of the lower part of the Middle Aalenian (*cf.* Callomon and Chandler, 1990; Contini *et al.*, 1997) ; (2) an assemblage composed of ammonites of the genus *Ludwigia* represented by *Ludwigia* (*Ludwigia*) *murchisonae* (Sowerby) (M) – and *Ludwigia* (*Pseudographoceras*) cf. *literata* (Buckman) (m)[13] (Pl. 4: 4–6) whose occurrence indicates the upper part of the Murchisonae Subzone of the Murchisonae Zone of the Middle Aalenian (see Callomon and Chandler, 1990; Contini *et al.*, 1997; Rulleau *et al.*, 2001); (3) an assemblage composed of ammonites of the genus *Brasilia*[14] represented by specimens of *Brasilia* (*Brasilia*) *bradfordensis* Buckman (Pl. 4: 2,3) indicative of the Bradfordensis Subzone of the Murchisonae/Bradfordensis Zone of the Middle Aalenian (*cf.* Callomon and Chandler, 1990; Contini *et al.*, 1997; Rulleau *et al.*, 2001); (4) an assemblage composed of *Graphoceras* including *Graphoceras* (*Graphoceras*) *concavum* (Sowerby)[15] (Pl. 4: 7; ? Pl. 5: 3) indicative of the Concavum Zone of the Upper Aalenian (see Contini *et al.*, 1997). Moreover, there occur commonly lytoceratids (*Lytoceras*, *Megalytoceras*) and phylloceratids (*Phylloceras*, *Calliphylloceras*) whose attribution to particular ammonite assemblages is difficult due to the wide stratigraphical ranges of the species (*cf.* Kalinichenko and Kruglov 1971, pl. 2: 1–11; note, however, that a form illustrated therein in fig. 11 is *Calliphylloceras*, and not as indicated *Tatrophylloceras* which is close to *Ptychophylloceras* –see *e.g.* Rulleau, 1998).

The lowest part of the crinoidal limestones of unit AVI yielded an ammonite referred to as *Otoites sauzei* (d'Orbigny) by Kalinichenko *et al.*(1965a; 1965b, p. 46–47, pl. 2: 2) indicative of the Propinquans (=Sauzei) Zone of the Lower Bajocian (Rioult *et al.*, 1997), and a number of brachiopods indicative of the Lower Bajocian (Kruglov, 1971). Possibly from the same unit came the specimen of *Stephanoceras humphriesianum* (d'Orbigny) illustrated by Leschukch and Hotsanyuk (2002, pl. 1: 3а–в) indicative of the Humphriesianum Zone of the uppermost Lower Bajocian. This, together with sedimentological data, indicates that at the base of unit A VI a marked stratigraphical hiatus occurs which covers a large part of the Lower Bajocian.

The greenish limestone packet several tens of centimetres thick, crowded with ammonite shells (*Phylloceras*, *Lytoceras*, *Taramelliceras*, *Orthaspidoceras*, *Nebrodites*) occurring in the upper part of unit AVII yielded the stratigraphically important: *Orthaspidoceras uhlandi* and *Nebrodites* sp. which indicate the presence of the Uhlandi Subzone, representing the uppermost part of the Herbichi Zone, and possibly the Acanthicum Zone, and thus the junction of the Lower and Upper Kimmeridgian (see *e.g.* Sarti, 1993).

UPPER TECTONIC UNIT (B)

Lithology and lithostratigraphy (Figs 6 and 10)

The lowermost stratigraphic unit (BI) is composed of gray and gray-greenish, well bedded crinoidal limestones (beds from 0.1–0.5 m in thickness) with black cherts, and intercalations of crinoidal marl (a few centimetres in thickness). The visible part of the unit (base not exposed) is about 12 metres thick.

A younger unit (BII) is composed of nodular limestones of the ammonitico-rosso facies. Its total thickness is close to 4 metres, but in some sections in the quarries it is reduced due to tectonic reasons. The lower part, about 0.65 m thick, is developed as yellowish and greenish marly nodular limestones with abundant ammonites. The ammonite shells are often corroded on one side and covered with thin ferruginous crusts. Of other faunal elements there occur belemnite rostra and tests of regular echinoids. The occurrence of the filament (*Bositra*) microfacies is typical of this stratigraphic interval. Towards the top of the unit, the nodular character of

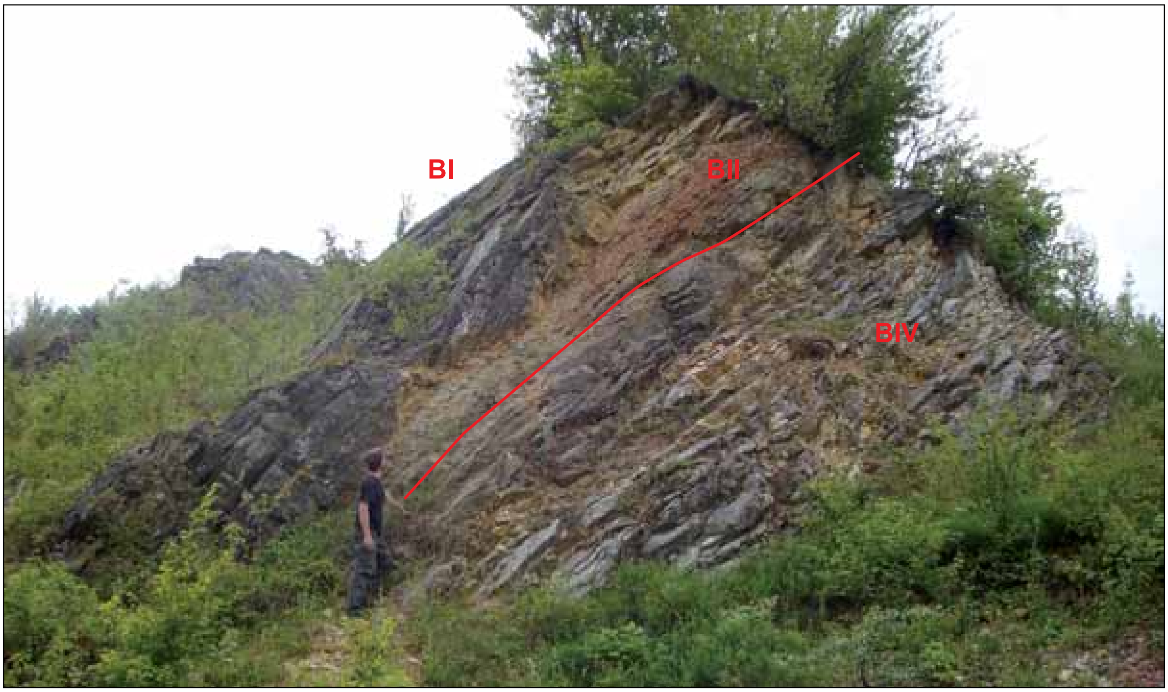

Fig. 10. Fragment of the NW part of the Priborzhavske quarries showing the deposits of units BI and BII in tectonic contact with unit BIV of the upper tectonic unit (B)

the limestones is preserved, but the amount of marly matrix markedly diminishes. The filament microfacies which still occurs in the lower part of this interval is replaced by the planktonic foraminifer (*Globuligerina*) microfacies at about 1.75 m above the base of the unit. Ammonites are still numerous but poorly preserved and difficult for to extract from the rock.

Unit BIII is represented by whitish, well bedded massive limestones, where the lowermost part of the unit reveals an indistinct nodular structure, and contains more abundant ammonites. The lower part of the unit up to about 10 metres from its base is composed of medium to thick-bedded limestones of the *Saccocoma* microfacies. The limestone beds become more thin (from a few centimetres up to 0.3–0.4 m thick) in the upper part of the unit, attaining about 6 m in thickness, and the number of bioclasts increases; there appear also intercalations of crinoidal limestone showing erosional lower boundaries.

The youngest Jurassic deposits, representing the unit BIV, are white, well bedded micritic limestones with black cherts of the maiolica facies type. The minimum thickness of the unit is 6 metres; the calpionellid microfacies with *Crassicolaria* is recognized in lowermost part of the unit.

Biostratigraphy and chronostratigraphy

The oldest deposits (unit BI) developed as gray and gray-greenish, well-bedded crinoidal limestones with cherts did not yield any ammonite fauna. Their age must be, however, Bajocian, according to the stratigraphical position of directly younger deposits.

The lower part of the nodular limestones of the ammonitico-rosso facies of unit BII, about 1.75 m in thickness, yielded many ammonites, especially commonly occurring phylloceratids *(Holcophylloceras*, *Ptychophylloceras*, *Phylloceras*, *Partschiceras*) and lytoceratids (*Lytoceras*, *Nannolytoceras*). Of the most stratigraphically important is *Nannolytoceras* cf. *tripartitum* (Raspail) (Pl. 5: 5–7) whose occurrence, together with *Dimorphinites* cf. *dimorphus* (d'Orbigny) (Pl. 5: 8) in the oldest beds of the unit, about 0.75 m in thickness, indicates the upper part of the Parkinsoni Zone of the uppermost Bajocian. This is consistent with the occurrence in the same beds of perisphinctids (*Vermisphinctes* sp.) and oppeliids (*Oxycerites* sp.) (see *e.g*. Galácz, 1980; Pavia *et al.*, 2008; *cf.* also Wierzbowski *et al.*, 1999). The occurrence of a fragment of *Spiroceras*[16] (Pl. 5: 4) in the lowest bed of the unit is also worthy of notice: the ammonites of this genus are known to occur in the Upper Bajocian, ranging up as high as the Parkinsoni Zone (see Rioult *et al.*, 1997). There are no findings of important stratigraphically ammonites in the younger beds of the lower part of the nodular limestones; it should be remembered, however, that the deposits representing the lower part of unit BII are developed in the filament (*Bositra*) microfacies whose stratigraphic range in the Pieniny Klippen Belt corresponds to the Middle Jurassic – especially the uppermost Bajocian–Bathonian (see Wierzbowski *et al.*, 1999; Réhakova *et al.*, 2011).

The upper part of the unit BII, about 2.5 m in thickness yielded only a few poorly preserved ammonites including *Perisphinctes* (? *Arisphinctes*) sp. found about 3.3 m above the base of the unit BII, indicating the Middle Oxfordian. The occurrence of the planktonic foraminifer (*Globuligerina*) microfacies also indicates the Oxfordian age of the deposits (see Wierzbowski *et al.*, 1999; Réhakova *et al.*, 2011).

The overlying unit BIII represented by whitish, well bedded limestones also yielded only a few ammonites (*Aspidoceras* and *Taramelliceras*) found at about 2.5 m from the base; these ammonites, along with occurrence of the *Saccocoma* microfacies (recognized up to about 10 metres from the base of the unit), indicate the Kimmeridgian and possibly Early to early Late Tithonian age of the deposits (see Réhakova *et al.*, 2011).

The upper part of the unit BIII, about 6 metres in thickness, did not yield any diagnostic fossils, but in the lowermost part of the overlying white, well bedded micritic limestones with black cherts of the maiolica facies type (unit BIV), calpionellids of the genus *Crassicolaria* occur commonly. This genus indicates the Crassicolaria Zone of the Upper Tithonian.

SUCCESSION AT PERECHIN

A large disused quarry at Perechin, about 18 kilometres north-east of Uzhorod, closed in 1967 and completely overgrown nowadays, offered a succession of Jurassic deposits described only in a general outline in some older papers (see *e.g.* Kruglov, 1971; Slavin, 1972, and earlier papers cited therein). These Jurassic deposits, steeply inclined towards the NNE, were situated in an overturned position, and tectonic repetitions of the Lower Jurassic deposits have been recognized in the north-eastern and south-western parts of the quarry. The description of the succession given below with the distinguished rock-units herein, is based on the older descriptions.

The oldest Early Jurassic deposits (unit PI), 26 metres in thickness (base not exposed), are developed as dark-gray and brownish shales, clays, and sandstones with intercalations of gray limestones; the upper part of the unit, composed of clays with intercalations of limestones, about 2 metres in thickness, yielded bivalves (*Cardinia* and *Gryphea*) (see Kruglov, 1971, p. 105; Slavin, 1972, fig. 19).

Younger are light-gray fucoid marls and limestones with intercalations of greenish and black clays (unit PII): they yielded ammonites of the genera *Arnioceras*, *Arietites* and *Coroniceras* (see Kalinichenko and Kruglov, 1969, p. 34–35, pl. 1: 1–4) in their lower part indicative of the Lower Sinemurian, as well as *Echioceras* (see Kalinichenko and Kruglov, 1969, p. 36, pl. 2: 36) in their upper part indicative of the Upper Sinemurian. The total thickness of these deposits attains about 20–25 m. The topmost part of the unit shows the presence of dark-gray marls and clays, and yellowish-greenish clays, about 3 metres in thickness, which yielded "*Hildoceras* cf. *bastiani* Fucini" (see Kruglov, 1971, p. 106; Slavin, 1972, p. 137 – specimen not illustrated); it should be remembered that the species in question actually belongs to the genus *Fuciniceras* (see *e.g.* Géczy and Meister, 2007, p. 212), whose occurrence is limited to the Lower Pliensbachian and the lower part of the Upper Pliensbachian.

Still younger deposits (unit PIII) are reddish clays, about 1 metre in thickness, with unidentifiable fragments of ammonites, and overlying variegated quartz sandstones with large, well rounded pebbles and belemnites, about 2 metres in thickness (Slavin, 1972).

Younger deposits (unit PIV) are represented by limestones, in the lower part pinkish and greenish with common flat cherts and containing common belemnites; intercalations of sandstones appeared in the upper part of the unit, whose total thickness attained about 15 metres (Slavin, 1972, fig. 19).

Above are gray and pinkish crinoidal limestones (unit PV), about 5 metres in thickness; these are followed by nodular limestones (unit PVI; "breccia-like limestones" see Slavin, 1972), about 6 metres in thickness, and overlain by white pelitic limestones (unit PVII) with rare cherts, at least 10 metres in thickness.

SUCCESSION AT NOVOSELITSA

A local, working quarry above Novoselitsa village, about 8 kilometres NNW of Perchin, at the Ukrainian/Slovakian border, shows the succession of Jurassic deposits which was studied by the present authors in 1999–2000. These deposits are very steeply inclined either towards the north or towards the south, or are placed vertically. The beds are locally strongly tectonically disturbed, and this results in thinning and/or wedging out of particular rock units, and especially those consisting of clayey-marly deposits. The succession of deposits (units NI–NV) can be interpreted as follows:

Unit NI consists of gray-bluish shales and marly limestones with belemnites and poorly preserved ammonites (phylloceratids); the deposits are at least 4–5 metres in thickness but neither their base nor the top are visible.

Unit NII, in its lowermost part about 0.3 m in thickness, consists of red micritic limestones and marls with limestone clasts, ammonites and belemnites. The upper part of the unit, about 1 m in thickness, is represented by gray-greenish marly limestones: red limestone clasts with ferrugineous coatings, corroded ammonites, and ferrugineous ooid grains are encountered. The fossils in the red limestone include: ammonites (*Hildoceras* sp., unidentified hildoceratids, and phylloceratids), belemnites and gastropods. The presence of *Hildoceras* indicates the Bifrons Zone of the Middle Toarcian (*e.g.* Elmi *et al.*, 1997).

Unit NIII consists of massive gray-yellowish and pinkish crinoidal limestones; the total thickness of the unit may attain a few tens of metres, and it was calculated as over 15 metres by Kruglov (1971). An ammonite of the genus *Stephanoceras*, referred to as *S. humphriesianum* (Sowerby), has been described from this unit in Novoselitsa quarry by Kalinichenko *et al.* (1965 b, p. 45–46, pl. 2: 1) which indicates the presence of the Humphriesianum Zone of the uppermost Lower Bajocian (*e.g.* Rioult *et al.*, 1997).

Unit NIV consists of gray-brownish and greenish nodular limestones with ammonites, at least a few metres in thickness. The lower part of the unit, about 1.5 m in thickness, yielded numerous ammonites: *Parkinsonia* (*Durotrigensia*) *bomfordi* Arkell[17] (Pl. 6: 1), various perisphinctids, phylloceratids (*Holcophylloceras*) and lytoceratids (*Lytoceras*, *Nannolytoceras* cf. *tripartitum* (Raspail)). The occurrence of *P. bomfordi* is indicative of the Bomfordi Subzone representing the uppermost part of the Parkinsoni Zone, *i.e.* the topmost part of the Upper Bajocian (*e.g.* Rioult *et al.*, 1997), whereas *N.tripartitum* is indicative of the uppermost Bajocian and lowermost Bathonian (*e.g.* Pavia *et al.*, 2008).

Unit NV consists of whitish and gray, well bedded micritic limestones; an horizon with phosporite nodules and belemnites has been recognized at the top of the unit; the thickness of the unit is only a few metres, but it is possibly markedly tectonically reduced.

COMMENTS ON AMMONITES

The following abbreviations are used in the descriptions of the ammonites: D – diameter of specimen in millimetres, Wh – whorl height in relation to diameter of specimen; Ud – umbilical diameter in relation to diameter of specimen; Wb – whorl breadth in relation to diameter of specimen, PR – number of primary ribs per whorl.

[1]This small specimen (Pl. 1: 1) attaining about 20 mm in diameter consists of the phragmocone and a part of the body chamber about one quarter of a whorl long. The coarse ribs, clearly visible on the body chamber, show a somewhat S-shaped appearance, being markedly prorsiradiate in the dorsolateral part of the whorl and more rectiradiate in the ventrolateral part; the ribs are single and biplicate with the furcation point at the umbilical wall; the ventral groove is well developed. Although small and not complete, the specimen can be well compared with *Angulaticeras* (*Sulciferites*) *ventricosum* (Sowerby) as interpreted by Bloos (1979, p. 145–149, fig. 1: 1–8) and Meister *et al.* (2010, p. 68, 70, fig. 32: m–n, q–r, u–v – with synonymy given).

[2] Several specimens of the genus *Echioceras* have been discovered. The most common is *Echioceras raricostatoides* (Vadasz): the specimens (Pl. 1: 2–5) show a rounded whorl section, are strongly evolute (at D = 70–75 mm, Wh = 0.21–0.23, Ud = 0.62–0.64), and coarsely ribbed (at D = 30–70 mm, PR = 22–26); the single rectiradiate ribs become swollen at the ventral margin, and the venter bears well developed keel. Less common is *Echioceras raricostatum* (Zieten) (Pl. 1: 6a–b) represented by very evolute specimen (at D = 52–75 mm, Wh = 0.20, Ud = 0.65–0.69), which is coarsely ribbed, and shows a low, depressed whorl section (at D = 52 mm, Wb = 0.27). The difference between the two species lies mostly in the whorl section (see *e.g.* Schlegelmilch, 1976, p. 50–51, pl. 21: 10, 11; Schlatter, 1991, p. 34–35, pl. 2: 2–6). The ammonites referred to as *Androgynoceras capricornus* (Schlotheim) and *A.* cf. *maculatum* (Young et Bird) by Kalinichenko and Kruglov (1969, pl. 2: 3, 4 а–б–в) from Priborzhavske, show a well developed ventral keel and should be placed in the genus *Echioceras* – possibly close to *Echioceras raricostatoides* (Vadasz). Three specimens found at a single level differ markedly from the forms described above in the uniform development of their ribs which do not become swollen at the ventral margin. The specimens attain about 70–80 mm in diameter where the modification of the ribbing showing the proximity of the final peristome is observed (Pl. 1: 7–9). Although fragmentarily preserved and compressed they can be safely compared with *Echioceras quenstedti* (Schafhäutl) as interpreted by Blau (1998, p. 205–206, pl. 4: 1, 2) who recognized as its younger synonyms several other names of the “primitive” *Echioceras* species like *e.g*. *E. rhodanicum* Buckman, *E. aenum* Trueman et Williams and *E. typicum* (Buckman).

[3] An incomplete, strongly evolute specimen (Pl. 1: 11) about 40 mm in diameter (at D = 41 mm, Wh = 0.22, Ud = 0.56) shows weakly prorsiradiate, fairly dense single ribs (at D = 25 mm, PR = 28). The ribs are fairly sharp on the whorl sides, becoming weaker on the ventral margin which is rounded, and the venter bears a low blunt keel possibly

bordered by weak grooves; the whorl section is subquadrate. The specimen seems similar to *Ortechioceras*, possibly its early representatives like *Ortechioceras recticostatum* Trueman et Williams (see *e.g.* Schlatter, 1991, p. 40–41, pl. 4: 1–4) which occupy a somewhat intermediate position between the genera *Echioceras* and *Paltechioceras*, and it is referred to here as *Ortechioceras* cf. *recticostatum.*

[4] Another specimen (Pl. 1: 10) found in the same bed as the *O.* cf. *recticostatum* discussed above is represented by an incomplete outer imprint without the venter preserved: the specimen shows very dense weakly curved single ribs with about 50 primary ribs per whorl at D = 25 mm. Such ribbing is encountered in early representatives of the genus *Paltechioceras* such as *P. boehmi* (Hug) (see *e.g.* Blau, 1998) and the specimen studied is referred with reservation to that species.

[5] Ammonites of the genus *Uptonia* are represented mostly by phragmocones attaining large diameters with the body chamber/phragmocone boundary at about 140–150 mm diameter. The specimens (Pl. 2: 1, 2) show moderately dense simple ribbing (about 40–50 primary ribs at D = 140–165 mm) which swing slightly forwards as they cross the venter, forming well developed chevrons. The ribs are prorsiradiate, thinner close to the umbilicus, and becoming wider towards the ventral side. The whorl section is compressed, rectangular. Although fragmentarily preserved, they can be referred to as *Uptonia* cf. *jamesoni* (Sowerby) according to the interpretation of the species by Géczy and Meister (2007, p. 193–194, with synonymy given). A well preserved specimen of *Uptonia jamesoni* (Sowerby) was described and illustrated by Hotsanyuk and Leschukch (2006, pl. 5: 1a–б) from Priborzhavske quarry.

[6] A single whorl fragment about 90 mm in diameter, and representing the phragmocone, shows loosely spaced single ribs (about 15 per half a whorl) which bear small tubercles at the ventral margin. The venter is fairly wide and weakly convex. The specimen seems similar to some forms of the genus *Platypleuroceras* like *Platypleuroceras tenuilobus* (Quenstedt) which occupy an intermediate position between the genera *Platypleuroceras* and *Uptonia* (see Meister, 1986), but due to its poor preservation it is referred to the genus *Platypleuroceras* with reservation.

[7] A single well preserved specimen of *Pleuroceras spinatum* (Bruguière) has a diameter about 85 mm (at D = 82 mm, Wh = 0.34, Ud = 0.43, PR = 24). The specimen (Pl. 2: 3) is heavily ribbed; a very strong ventrolateral tubercle is developed at the end of each single rib, the tubercles are bent towards the aperture, and then separated by grooves from the well developed keel. The specimen compares well with the neotype of the species as illustrated by Dean *et al.* (1961, pl. 71: 1). Similar forms have been described from the Carpathians by Rakús (1987, p. 18–19, pl. 1: 5, 6).

[8] A specimen about 60 mm (Pl. 3: 5) in diameter shows strongly falcate ribbing, stronger and more distant on the inner whorls up to 30 mm diameter, similar to that of the holotype of *H. falcifer* (see Dean *et al.*, 1961, pl. 72: 3a, b; Schlegelmilch, 1976, pl. 45: 4), and more dense on the last half whorl; at D = 61 mm, Wh = 0.46, Ud = 0.25.

[9] An incomplete specimen about 100 mm in diameter (Pl. 3: 4), strongly evolute with falcate ribbing represented by a short umbilical stem, and a much longer outer part of the rib. This specimen is similar to representatives of the type species of *Hildaites* – *H. subserpentinum* (Buckman) as *e.g.* illustrated by Schlegelmilch (1976, pl. 45: 1).

[10] The fragmentary specimen (Pl. 3: 1) referred to as *Hildoceras* cf. *sublevisoni* Fucini shows the presence of strong falcoid ribs without a lateral groove which is a feature of the oldest *Hildoceras* representatives (see Elmi *et al.*, 1994; 1997). Another specimen (Pl. 3: 3) is *Hildoceras crassum* Mitzopoulos: the specimen is 85 mm in diameter and represents the phragmocone: at D = 85 mm, Wh = 0.34 and Ud = 0.39. The fairly strong, loosely spaced ribs (at D = 55 mm the number of outer ribs equals 33), and poorly developed lateral groove, show a marked similarity to those of specimens of the species illustrated by *e.g.* Roulleau *et al.* (2001, pl. 10: 1a,b). More troublesome is the specific identification of a wholly sepatate large specimen of the genus *Hildoceras* (Pl. 3: 2); the specimen is 140 mm in diameter and shows fairly evolute coiling of the outer whorl (at D = 141 mm, Wh = 0.30, Ud = 0.46), but becomes less evolute in the inner whorls. The character of ornamentation (fairly dense outer ribs equaling about 46 per whorl at D = 55 mm) and the initial development of the lateral groove indicates similarity to *Hildoceras lusitanicum* Meister – see the specimens illustrated by Elmi (1967, fig. 45.1) and Roulleau *et al.* (2001, pl. 9: 1a, b; pl. 10: 2a, b); but the less evolute coiling of the inner whorls suggests similarity to *H. tethysi* Géczy (see *e.g.* Elmi *et al.*, 1997, pl. 9: 15). Both species are closely related, representing a similar stage in the evolution of their ornamentation (Elmi *et al.*, 1994). The specimen in question is thus referred to as *Hildoceras* ex gr. *lusitanicum* Meister – *tethysi* Géczy.

[11] The specimens illustrated by Kalinichenko and Kruglov (1971) represent two different groups: (1) a group consisting of "*Leioceras uncum*" (*op. cit*., pl. 2: 4) and "*Pleydellia aalensis*" (*op. cit*., pl. 2: 2) – which group, however, has nothing in common with the true *Pleydellia* as shown by their strongly falcate ribbing with the strongly prorsiradiate course of the ribs on the umbilical margin in the specimen in question; both specimens show irregular ribbing typical of the genus *Leioceras*, and fairly strong ornamentation which is found in late representatives of the genus like *L.* (*Cylicoceras*) *uncinatum* Buckman (*cf.* Contini, 1969, p. 21–22, pl.

9: 4) or *L.* (*Cypholioceras*) *comptum evolutum* Contini (see Contini, 1969, p. 19–21, pl. 8: 9, 10; pl. 9: 1–3); these forms correspond generally to the *Leioceras comptocostosum* as distinguished by Chandler and Callomon (2009); (2) a group represented by "*Leioceras acutum*" of Kalinichenko and Kruglov (1971, pl. 2: 3) which shows much more regular ribbing and resembles representatives of weakly ornamented *Ancolioceras*/*Staufenia*, like *A. opalinoides* (Buckman); a similar specimen referred to as *Leioceras acutum* (Quenstedt) was illustrated by Leschuk and Hotsanyuk (2002, pl. 1: 1a–в).

[12] A nicely preserved specimen (Pl. 5: 1) about 145 mm in diameter represented by the phragmocone (up to about 85 mm diameter) and body chamber about 2/3 whorl long; the whorl section is high oval with a well developed keel on the ventral side; the coiling is moderately involute (at D = 103 mm, Wh = 0.31, Ud = 0.27); the ribbing is falcate with two-three secondary ribs per primary rib; the ribbing on the inner whorls up to about 50 mm diameter is distant with well developed occasional swellings of the short primary ribs; then the ribs become more uniformly developed: the number of primary ribs per whorl equals from about 15 at D = 40 mm up to 24 at D = 100 mm; at larger diameters the ribbing disappears. The specimen corresponds perfectly to specimens of *Staufenia sinon* (Bayle) – described by *e.g*. Contini (1969, p. 31–32, pl. 11: 1–4; pl. 12: 1–3) and Schlegelmilch (1985, pl. 10: 4).

[13] Of several specimens referred to the genus *Ludwigia*, those better preserved showing distant and strong ribbing consisting of strongly prorsiradiate primaries and markedly rursiradiate secondaries, and may be attributed to co-occurring macro and microconchs: a larger more involute *Ludwigia* (*L.*) *murchisonae* (Sowerby) and a smaller more evolute (although represented by phragmocones only) – *Ludwigia* (*Pseudographoceras*) cf. *literata* (Buckman) (Pl. 4: 4–6) (see *e.g.* Contini, 1969; *cf.* also Callomon and Chandler, 1990).

[14] A typically developed assemblage of *Brasilia* comprises compressed forms with dense and fine ribbing, showing markedly involute coiling on the inner whorls (at D = 53 mm, Wh = 0.44, Ud = 0.225) which becomes less involute on the outer whorl (at D =103 mm, Wh = 0.40, Ud = 0.315). The specimens (Pl. 4: 2, 3) show marked similarity to *B.* (*B.*) *bradfordensis* Buckman as widely interpreted by Contini (1969); see also Rulleau *et al.* (2001, pl. 21: 5; pl. 22: 1, 2).

[15] A well preserved phragmocone (Pl. 4: 7) about 60 mm in diameter shows highly involute coiling at larger diameters (at D = 58 mm, Wh = 0.46, Ud = 0.24) but more evolute coiling of inner whorls; the steep umbilical wall, coarse ornamentation of the inner whorls, strongly compressed whorl section, and the rursiradiate course of the secondary ribs enable its identification as *G.* (*G.*) *concavum* (Sowerby) (*cf.* Contini, 1969, p. 61–67; pl. 21: 1–9, pl. 22: 1–3).

[16] A single specimen is represented by a fragment of a whorl about 15 mm long; the simple ribs are slightly prorsiradiate and bear two rows of small tubercles: one at about two/thirds of the whorl height and another at the ventrolateral margin; a furrow occurs in the middle of the ventral side. The features correspond well to the characteristics of the genus *Spiroceras* (see *e.g.* Galácz, 1980) but the specimen (Pl. 5: 4) is too fragmentary preserved for closer identification.

[17] A large specimen (Pl. 6 : 1) about 160 mm in diameter consisting of the phragmocone (up to 140 mm diameter), and initial part of the body chamber. The coiling is weakly evolute (at D = 155 mm, Wh = 0.34, Ud = 0.37); the whorl section is wide oval with a fairly wide ventral side. The ribbing consists of fairly dense, prorsiradiate ribs (at diameters 105 mm and 155 mm, the numbers of primary ribs per whorl equal 36 and 34, respectively). The number of secondary ribs per primary equals 3.0 at D = 140 mm. Both the whorl section and the character of ribbing bear a close resemblance to those of the holotype of *Parkinsonia bomfordi* as described by Arkell (1956, p. 157, text-fig. 55: 3ab). The species has been recently described and discussed by Matyja and Wierzbowski (2000, p. 205, pl. 5: 1, 2).

GENERAL STRATIGRAPHY OF THE DEPOSITS, AND THEIR PALAEOTECTONIC INTERPRETATION

The Jurassic deposits of the Pieniny Klippen Belt at Priborzhavske, Perechin, and Novoselitsa quarries in the Transcarpathian Ukraine, as well as those at Beňatina quarry in easternmost Slovakia, show several features in common indicating that they all were formed in a similar paleotectonic position (see Krobicki *et al.*, 2003; Schlőgl *et al.*, 2004). The general sequence of the deposits may be summarized here as follows (Fig. 11).

The oldest are clays and sandstones with, appearing upwards, intercalations of marls and marly limestones; the full succession of these deposits is poorly exposed, however, in the Ukrainian sections. The upper part of these deposits is known at Priborzhavske, in the succession of the lower tectonic unit, where it corresponds to units AI and AII (see also Krobicki *et al.*, 2012). Similar deposits, possibly even more fully exposed in the past, but not accessible nowadays, correspond to unit PI from the Perechin quarry succession (see *e.g.* Kruglov, 1971; Slavin, 1972). The deposits in question may be possibly attributed to the Hettangian in their lower parts (*e.g*. Kruglov, 1971), but their uppermost part (unit AI of Priborzhavske) has yielded already a Lower Sinemurian ammonite. These deposits were distinguished in Ukraine as a lower part of the Perechinska svita (Slavin *et al*., 1967; see

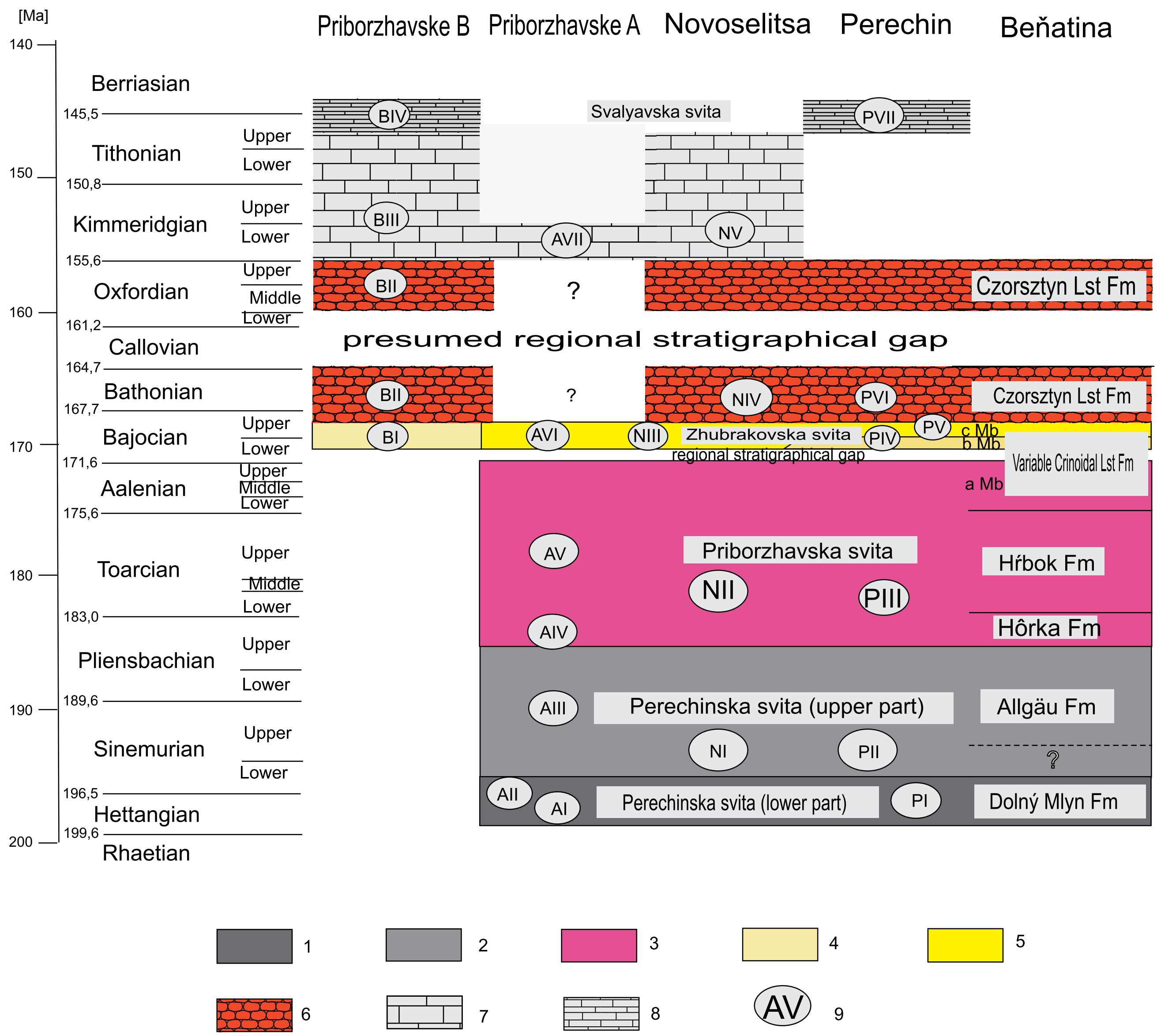

Fig. 11. Distribution of the main lithostratigraphic and facies units in the Priborzhavske-Perechin-Novoselitsa (Transcarpathian Ukraine) – the Beňatina zone (easternmost Slovakia) in the Pieniny Klippen Belt, given on the background of stratigraphical time scale (after Ogg, 2004)

1 – siliciclastic and marly deposits; 2 – fleckenkalk–fleckenmergel deposits; 3 – diversified and condensed deposits; 4 – crinoidal packstones with cherts and intercalations of micritic limestones; 5 – crinoidal grainstones; 6 – ammonitico-rosso type limestones; 7 – micritic limestones; 8 – maiolica type limestones with cherts; 9 – lithostratigraphic units

also Kalinichenko and Kruglov, 1969). In Beňatina quarry in easternmost Slovakia, closely corresponding deposits are placed in the Dolný Mlyn Formation; they yielded in their uppermost part ammonites indicative of the Semicostatum Zone of the Lower Sinemurian (Schlőgl *et al.*, 2004). In general facies development, the deposits in question show a transitional character between the gresten facies and the fleckenkalk/fleckenmergel facies. It should be remembered that at the top of the deposits in Priborzhavske quarry (top of unit AII) a level with volcanic ash has been recognized with abundant pyroclastic quartz grains. This rhyolite type of pyroclasts represents the only recognized volcanogenic material in the sections studied.

Younger deposits are spotty alternating marls, marly limestones, and limestones. These were distinguished as unit AIII in the succession of the lower tectonic unit of Priborzhavske quarry (see Krobicki *et al.*, 2012); in Perechin quarry (see Kruglov, 1971; Slavin, 1972) as the fucoid marls and limestones and referred herein as unit PII. Similar deposits, but tectonised and fragmentarily cropping out are known also from Novoselitsa quarry (unit NI). The general thickness of these deposits attains from about 17 to about 20–25 metres. The ammonites demonstrate that the stratigraphical range of the deposits is from some part of the Lower Sinemurian up to the Lower Pliensbachian (including the Jamesoni Zone and possibly ranging up to the upper Lower Pliensbachian – lower Upper Pliensbachian). The deposits in the Transcarpathian Ukraine are distinguished as an upper part of the Perechinska svita (Slavin *et al.*, 1967). Similar deposits in Beňatina quarry in easternmost Slovakia are placed in the Allgäu Formation, and their stratigraphic position ranges at least from the Upper Sinemurian (Oxynotum Zone) up to the Upper Pliensbachian (Spinatum Zone) – see Schlőgl *et al.*, 2004. In general facies terms the deposits correspond to the fleckenkalk/fleckenmergel facies.

The initial sedimentation of these two stratigraphical units of the gresten to – fleckenkalk/fleckenmergel facies during the Early Jurassic, from the Hettangian (?) and Sinemurian up to the Late Pliensbachian, closed the first stage of the development of fairly uniform dark deposits having a wide distribution in the northern Carpathian basins including the Pieniny Klippen Basin.

Markedly different and highly variable deposits directly overlie these Lower Jurassic deposits in the Priborzhavske quarries. The initial unit of small thickness, not attaining usually more than 3 metres, commences with glauconitic sandy marls with intercalations of sandy limestones, replaced upward by glauconitic sandy crinoidal limestones. The ammonites indicate the presence of the Spinatum Zone of the uppermost Pliensbachian. These deposits, well recognized in the succession of the lower tectonic unit, are distinguished as unit AIV (Krobicki *et al.*, 2012). Still younger, very highly condensed deposits at the same locality, corresponding to unit AV (Krobicki *et al.*, 2012), attain from several centimetres up to 0.25 m, but locally may be completely missing; in their lower part these are limestones with ferrugineous ooids and stromatolitic encrustations with ammonites representing some stratigraphical intervals of the Toarcian – the turn of the Lower and Middle Toarcian (Serpentinum to Bifrons zones), but possibly also some parts of the Upper Toarcian. These deposits are cut by neptunian dykes filled with laminated limestones with Lower Aalenian ammonites. Younger deposits are ammonite pavements with quartz pebbles, belemnite rostra, brachiopod and gastropods shells and fish teeth representing the uppermost Lower and the Middle – Upper Aalenian. It should be remembered, however that the same stratigraphical interval, corresponding at least to some parts of Lower as well as the Middle and Upper Aalenian, may be represented locally by more expanded deposits attaining about 8 m in thickness: clays/shales with intercalations of marls and limestones as described from Priborzhavske quarry by Kruglov (1971) as well as Kalinichenko and Kruglov (1971).

The detailed succession of the corresponding deposits in the quarries at Perechin and Novoselitsa has never been elaborated, mostly because of the strong tectonic deformations of these deposits, but nevertheless the occurrence of similar lithologies has also been reported here: (1) red clays and overlying variegated quartz sandstones with ammonites and belemnites (unit PIII), about 3 metres in thickness, in the quarry at Perechin (Slavin, 1972); (2) fragmentarily cropping out red limestones and marls with ferrugineous coatings, corroded ammonites, belemnites, and ferrugineous ooids (unit NII), in the quarry at Novoselitsa: ammonites indicate the presence of the Middle Toarcian. All these highly variable deposits have been distinguished as the Priborzhavska svita (Slavin *et al.*, 1967; Kruglov, 1971; Kalinichenko, Kruglov, 1971).

In Beňatina quarry in easternmost Slovakia the corresponding deposits differ a little, mostly in their somewhat less condensed character, but nevertheless they also show marked similarities. These are developed as (from the base, see Schlőgl *et al.*, 2004): (1) glauconitic sandstones and marlstones with ammonites of uppermost Pliensbachian age distinguished as the Hôrka Formation, about 3m in thickness; (2) red marls and marlstones with ammonites covering the whole Toarcian distinguished as the Hŕbok Formation, about 5 metres in thickness; (3) marly crinoidal limestones and marls with a marked sandy admixture, in a continuous succession with the underlying deposits, containing small phosphatized ammonites of Aalenian age, and about 2 metres in thickness; these deposits are distinguished as the lower part (member A) of informal "formation of variable crinoidal limestones" (Schlőgl *et al.*, 2004).

The appearance of highly condensed deposits in the Transcarpathian Ukraine in the Priborzhavske–Perechin–Novoselitsa sections referred to the Priborzhavska svita was possibly related to the rifting phase which began in the latest Pliensbachian and continued through the Toarcian and at least partly through the Aalenian as proved *e.g.* by the occurrence of Early Aalenian neptunian dykes in the Priborzhavske sections, and the highly variable lithology and thickness of the Aalenian deposits. The same phenomenon may be recognized in the succession in Beňatina quarry in easternmost Slovakia where deposits corresponding to the Hôrka Fm., the Hŕbok Fm., and to the lowermost part (member A) of the "formation of variable crinoidal limestones" do occur (*cf.* Schlőgl *et al.*, 2004) . The rifting at that time, distinguished as the Devín rifting phase, has been recognized in the Carpathian basins which were situated southwards of the Pieniny Klippen Basin, such as the North Tatric Ridge (Plašienka, 2003). The Devín rifting phase is not recognized in the Czorsztyn succession representing the northern part of the Pieniny Klippen Basin. This suggests that the original palaeogeographic position of the studied successions of the Priborzhavske–Perechin–Novoselitsa– Beňatina zone was in the southern part of the Pieniny Klippen Basin, which was postulated already by two of the authors of this study (BAM and AW in: Krobicki *et al.*, 2003, 2012; Schlőgl *et al.*, 2004).

Younger deposits in the area of study are crinoidal limestones represented either by thick bedded crinoidal grainstones (unit AVI in the succession of the lower tectonic unit in Priborzhavske, see Krobicki *et al.*, 2012; unit N III in the Novoselitsa succession), or by thin to medium-bedded crinoidal limestones with marly intercalations and with cherts (unit B I in the succession of the upper tectonic unit at Priborzhavske; see Krobicki *et al.*, 2012), and possibly limestones with cherts and intercalations of sandstones (sandy crinoidal limestones ?) in the upper part, representing unit PIV in the Perechin succession; the latter are followed by crinoidal limestones of unit PV, which represent possibly the grainstones, as may be concluded by their "coarse crystalline structure"(Slavin, 1972, p. 137). The deposits in question have been distinguished in the Transcarpathian Ukraine as the Zhubrakovska svita (see Slavin 1966, 1972; Slavin *et al.*, 1967; *cf.* also Kalinichenko *et al.* 1965). At the base of the deposits in question, especially at the base of the crinoidal grainstone units, a distinct stratigraphical hiatus at the turn of the Aalenian and Bajocian was indicated (see *e.g.* Kruglov, 1971; Kalinichenko and Kruglov, 1971b). As shown by the ammonites discussed herein the hiatus is situated in the lower part of the Lower Bajocian, well below the Propinquans (=Sauzei) Zone.

Crinoidal limestone units corresponding to those discussed above from the Ukrainian sections are known also from the Beňatina quarry in easternmost Slovakia (Schlőgl *et al.*, 2004). These are represented by two informal members of the "formation of variable crinoidal limestones": (1) member B, composed of crinoidal packstones, sometimes with admixture of detrital quartz grains, with cherts, and with micritic limestone layers showing nodular structure appearing in the upper part, (2) member C, composed of crinoidal packstones, locally also grainstones, without cherts (except the upper part) and with intercalations of micritic nodular limestone. No ammonites have been found in the quarry, but the deposits were estimated as being Bajocian in age on the basis of ammonites found in the directly underlying and overlying deposits.

It should be remembered that the stratigraphical position of the crinoidal limestone units in the Pieniny Klippen Belt was well established in the more western parts of the Pieniny Klippen Belt – from eastern Slovakia through Poland to western Slovakia – where two coeval formations covering the bulk of the crinoidal deposits have been distinguished – the Smolegowa Limestone Fm., composed mostly of crinoidal grainstones, and the Flaki Limestone Fm. developed commonly as crinoidal packstones with cherts; these are overlain in places by the Krupianka Limestone Formation, consisting of red somewhat condensed crinoidal limestones (*cf.* Birkenmajer, 1977). The stratigraphical hiatus at the base of the Smolegowa Limestone Fm., and of the Flaki Limestone Fm., is well documented by ammonite faunas and sedimentological features (Krobicki and Wierzbowski, 2004; Wierzbowski *et al.*, 2004; Krobicki, 2009), and it covers a large part of the Lower Bajocian up to the Propinquans Zone (and possibly the topmost part of the uppermost Aalenian).

The hiatus, and subsequent formation of crinoidal limestones, were related to the Early Bajocian uplift of the Czorsztyn Ridge whose steep northern slope was a source for "black flysch" deposits of the so-called "Pre-Late Albian Magura Basin" whereas the southern smaller scale tectonic scarps, inclined towards the Pieniny Klippen Basin, were settled by crinoid gardens, which resulted in formation of thick units of crinoidal limestone (Barski *et al.*, 2012). The occurrence of Early Bajocian crinoidal limestones with a marked stratigraphical hiatus at their base corresponds to the Bajocian Krasín rifting phase (Plašienka, 2003, p.89; see also Krobicki, 2009) which "strongly affected areas north of the North-Tatric Ridge". As a consequence of rifting, there appeared narrow ridges close to which the crinoidal grainstones were formed, and these occurred more distally – the well bedded crinoidal limestones with cherts sometimes associated with basinal micritic limestones (Wierzbowski *et al.*, 2004); both are known also from the Priborzhavske–Perechin–Novoselitsa– Beňatina zone.

The overlying deposits in the Ukrainian sections are indicative of a pelagic environment. These include: (1) the nodular limestones of the ammonitico-rosso facies of unit BII of the upper tectonic unit in the Priborzhavske succession, with ammonites and microfacies (microfacies with filaments of *Bositra*, followed by that with planktonic foraminifers of *Globuligerina*; see Krobicki *et al.*, 2012) indicating the stratigraphical interval from the uppermost part of the Bajocian (Parkinsoni Zone) up to the Oxfordian; (2) the nodular limestones from the Perechin succession (unit PVI; "breccia-like limestones" see Slavin, 1972) without biostratigraphical documentation; (3) nodular limestones with ammonites (unit N IV) of the Novoselitsa succession which yielded the oldest ammonites indicating the uppermost part of the Bajocian (Parkinsoni Zone). Also in Beňatina quarry in easternmost Slovakia the nodular limestones overlying the crinoidal limestones have yielded ammonites from the uppermost Bajocian (Parkinsoni Zone) up to the Middle Oxfordian (Schlőgl *et al.*, 2004; Schlőgl *et al.*, 2005). It is highly probable that the regional stratigraphical gap covering the interval from the top of the Bathonian up to the base of the Middle Oxfordian is present in the area of study, similarly as it is in other areas of the Pieniny Klippen Belt (see *e.g.* Reháková *et al.*, 2011). This stratigraphical gap corresponds everywhere to a marked change in microfacies from the filament (*Bositra*) microfacies below to the planktonic foraminifer (*Globuligerina*) microfacies above, which is also recognized in the sections studied; moreover, no ammonites of Callovian to Early Oxfordian age have been ever reported from the area of study. The gap is interpreted as a consequence of a fast opening of the new oceanic domain which resulted in a crisis in deposition (see Lewandowski *et al.*, 2005; Matyja and Wierzbowski, 2006; Reháková *et al.*, 2011).

Younger pelagic deposits are represented by well bedded micritic limestones representing unit AVII in the succession of the lower tectonic unit at Priborzhavske (Krobicki *et al.*, 2012). These beds contain a thin limestone packet crowded with ammonites occurring in the upper part of the unit: it yielded ammonites indicating the uppermost part of the Herbichi Zone, and possibly the Acanthicum Zone, and thus the junction of the Lower and Upper Kimmeridgian. It should be remembered that this stratigraphic interval in the Pieniny Klippen Basin often shows the presence of a marked accumulation of ammonite shells, which suggests a wider episode of condensation in the pelagic environment (see *e.g.* Wierzbowski, 1994; Reháková *et al.*, 2011). Similar deposits represented by whitish, well bedded limestones are known from the succession of the upper tectonic unit at Priborzhavske (unit BIII; see Krobicki *et al.*, 2012); their lower part shows the presence of the *Saccocoma* microfacies which is indicative of the Kimmeridgian to lower Upper Tithonian (see *e.g.* Reháková *et al.*, 2011); their upper part shows the presence of intercalations of crinoidal limestones showing erosional lower boundaries. Whitish and gray, well bedded micritic limestones, with phosporite nodules and belemnites at the top, has been recognized in the Novoselitsa succession (unit NV). All these deposits in the Pieniny Klippen Belt in Ukraine have been never formally ascribed to any formal stratigraphic unit. They show, however, a marked similarity to the Dursztyn Limestone Formation, and especially to the Sobótka Limestone Member of Birkenmajer (1977) well known from the Pieniny Klippen Belt in Poland and Slovakia.

The youngest deposits in the sections studied are white, well bedded micritic limestones with black cherts of the maiolica facies type known from the succession of the upper tectonic unit at Priborzhavske (unit BIV; see Krobicki *et al.*, 2012) as well as from the Perechin succession (unit PVII). They show the presence of the calpionellid microfacies, and may be attributed in their lower parts to the Upper Tithonian. These deposits are distinguished as the Svalyavska svita in the Pieniny Klippen Belt in the Transcarpathian Ukraine (see *e.g.* Slavin, 1966; Kruglov, 1971), and correspond to the Pieniny Limestone Formation in more western parts of the Pieniny Klippen Belt (Birkenmajer, 1977). Their occurrence is representative of basinal development, and was treated as indicative of the Svalyava facies zone (see Slavin, 1966, fig. 19).

The occurrence of pelagic deposits overlying the rift strata corresponds well with general subsidence and the development of a more uniform facies pattern during the post-rifting phase occurring throughout the Pieniny Klippen Basin, where the onset of pelagic sedimentation (ammonitico-rosso deposits and radiolarites) took place during the latest Bajocian (Wierzbowski *et al.*, 1999; Gedl, 2008), and continued nearly to the top of the Jurassic. The following Neo-Cimmerian phase of rifting appeared at the end of the Jurassic and continued during the Early Cretaceous in the Pieniny Klippen Basin (Birkenmajer, 1986; Golonka *et al.*, 2003; Krobicki *et al.*, 2010).

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PLATES

PLATE 1

Fig. 1. *Angulaticeras* (*Sulciferites*) *ventricosum* (Sowerby) sensu Bloos, 1988; ZI/54/01; Priborzhavske, unit AI, Lower Sinemurian, rubble

Fig. 2. *Echioceras raricostatoides* (Vadasz); ZI/54/02; Priborzhavske, unit AIII, middle part, Upper Sinemurian, Raricostatum Zone, Raricostatum Subzone

Fig. 3-5. *Echioceras raricostatoides* (Vadasz); ZI/54/05, 06, 11; phragmocone; Priborzhavske, unit AIII, middle part, Upper Sinemurian, Raricostatum Zone, Raricostatum Subzone

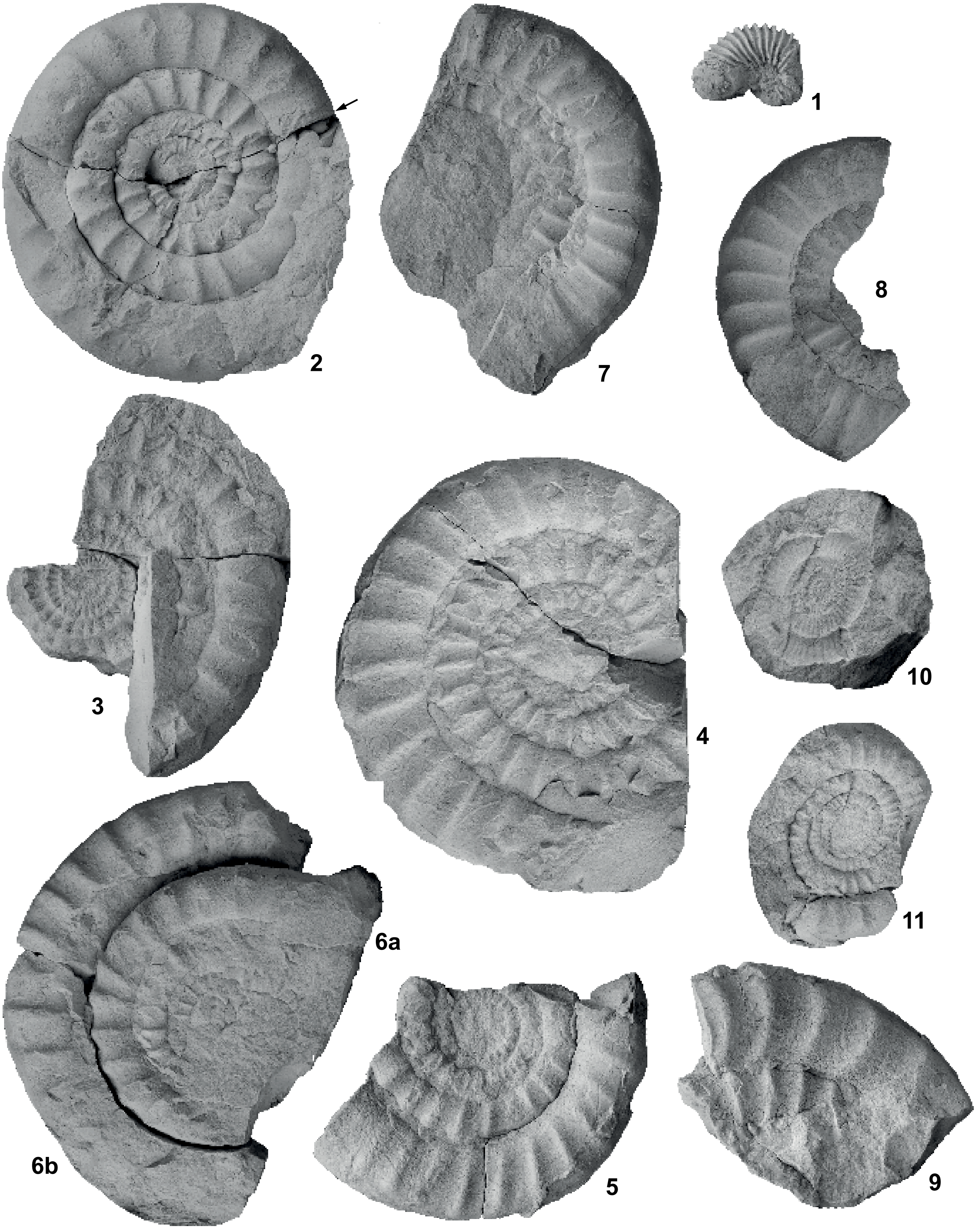
Fig. 6ab. *Echioceras raricostatum* (Zieten); ZI/54/10; a – phragmocone, b – body chamber; Priborzhavske, unit AIII, rubble, Upper Sinemurian, Raricostatum Zone, Raricostatum Subzone

Fig. 7-8-9. *Echioceras quenstedti* (Schafhäutl); ZI/54/12, 13, 14; Priborzhavske, unit AIII, rubble, Upper Sinemurian, Raricostatum Zone, Raricostatum Subzone

Fig. 10. *Paltechioceras* [? *P. boehmi* (Hug)]; ZI/54/04; Priborzhavske, unit AIII, middle part, Upper Sinemurian, Raricostatum Zone, Raricostatum Subzone

Fig. 11. *Ortechioceras* cf. *recticostatum* Trueman et Williams; ZI/54/03; Priborzhavske, unit AIII, middle part, Upper Sinemurian, Raricostatum Zone, Raricostatum Subzone

All specimens in natural size. The phragmocone/body chamber boundary is arrowed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6a
6b
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PLATE 2

Fig. 1-2. *Uptonia* cf. *jamesoni* (Sowerby); ZI/54/15, 16; phragmocone; Priborzhavske, unit AIII, upper part, Lower Pliensbachian, Jamesoni Zone, Jamesoni Subzone

Fig. 3. *Pleuroceras spinatum* (Bruguière); ZI/54/18; phragmocone; Priborzhavske, unit AIV, upper part, uppermost Pliensbachian, Spinatum Zone

All specimens in natural size


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PLATE 3

Fig. 1. *Hildoceras* cf. *sublevisoni* Fucini; ZI/54/23; phragmocone; Priborzhavske, unit AV, Middle Toarcian, Bifrons Zone, Sublevisoni Subzone

Fig. 2. *Hildoceras* ex gr. *lusitanicum* Meister – *tethysi* Géczy; ZI/54/22; phragmocone; Priborzhavske, unit AV, Middle Toarcian, Bifrons Zone, Sublevisoni Subzone

Fig. 3. *Hildoceras crassum* Mitzopoulos; ZI/54/21; phragmocone; Priborzhavske, unit AV, Middle Toarcian, Bifrons Zone, Sublevisoni Subzone

Fig. 4. *Hildaites* cf. *subserpentinum* (Buckman); ZI/54/24; phragmocone; Priborzhavske, unit AV, Lower Toarcian, Serpentinum Zone, Falcifer Subzone

Fig. 5. *Harpoceras falcifer* (Sowerby); ZI/54/25; phragmocone; Priborzhavske, unit AV, Lower Toarcian, Serpentinum Zone, Falcifer Subzone

All specimens in natural size


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PLATE 4

Fig. 1. *Leioceras* sp.; ZI/54/26; phragmocone; Priborzhavske, unit AV, neptunian dyke; Lower Aalenian, Opalinus Zone

Fig. 2. *Brasilia* (*Brasilia*) *bradfordensis* Buckman; ZI/54/27; phragmocone; Priborzhavske, unit AV, Middle Aalenian, Murchisonae/Bradfordensis Zone, Bradfordensis Subzone

Fig. 3. *Brasilia* (*Brasilia*) *bradfordensis* Buckman; ZI/54/29; Priborzhavske, unit AV, Middle Aalenian, Murchisonae/Bradfordensis Zone, Bradfordensis Subzone

Fig. 4. *Ludwigia* (*Ludwigia*) *murchisonae* (Sowerby); ZI/54/30; phragmocone; Priborzhavske, unit AV, Middle Aalenian, Murchisonae Zone, Murchisonae Subzone

Fig. 5. *Ludwigia* (*Pseudographoceras)* cf. *literata* Buckman; ZI/54/31; phragmocone; Priborzhavske, unit AV, Middle Aalenian, Murchisonae Zone, Murchisonae Subzone

Fig. 6. *Ludwigia* (*Pseudographoceras)* cf. *literata* Buckman; ZI/54/32; phragmocone; Priborzhavske, unit AV, Middle Aalenian, Murchisonae Zone, Murchisonae Subzone

Fig. 7. *Graphoceras* (*Graphoceras*) *concavum* (Sowerby); ZI/54/33; phragmocone; Priborzhavske, unit AV, Upper Aalenian, Concavum Zone

All specimens in natural size. The phragmocone/body chamber boundary is arrowed

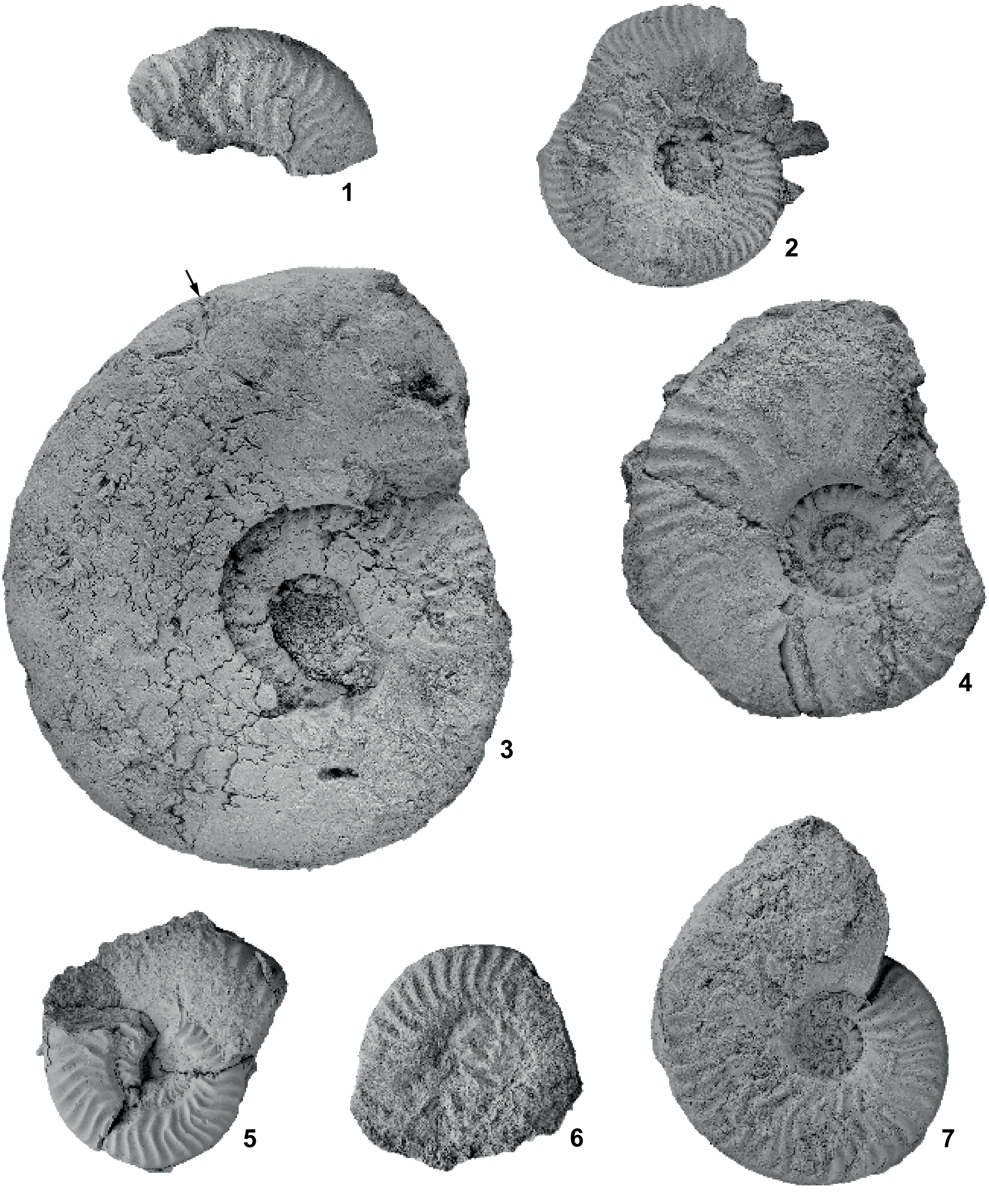
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PLATE 5

Fig. 1. *Staufenia sinon* (Bayle); ZI/54/34; Priborzhavske, unit AV, Middle Aalenian, Murchisonae Zone, Haugi Subzone

Fig. 2. *Bredyia* sp.; ZI/54/35; phragmocone; Priborzhavske, unit AV, Middle Aalenian, Murchisonae Zone, Haugi Subzone

Fig. 3. ? *Graphoceras* sp.; ZI/54/36; phragmocone; Priborzhavske, unit AV, ? Upper Aalenian

Fig. 4. *Spiroceras* sp.; ZI/54/37; Priborzhavske, unit B II; Upper Bajocian

Fig. 5–7. *Nannolytoceras* cf. *tripartitum* (Raspail); ZI/54/38 (phragmocone), 39, 40; Priborzhavske, unit BII, uppermost Bajocian, Parkinsoni Zone

Fig. 8. *Dimorphinites* cf. *dimorphus* (d'Orbigny); ZI/54/41; phragmocone; Priborzhavske, unit BII, uppermost Bajocian, Parkinsoni Zone

All specimens in natural size. The phragmocone/body chamber boundary is arrowed


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PLATE 6

Fig. 1. *Parkinsonia* (*Durotrigensia*) *bomfordi* Arkell; ZI/54/42; Novoselitsa, unit NIV, uppermost Bajocian, Parkinsoni Zone, Bomfordi Subzone

The specimen in natural size. The phragmocone/body chamber boundary is arrowed

1