Beňatina Klippe – lithostratigraphy, biostratigraphy, palaeontology of the Jurassic and Lower Cretaceous deposits (Pieniny Klippen Belt, Western Carpathians, Slovakia)

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Abstract. An abandoned quarry at Beňatina Klippe in the Pieniny Klippen Belt in eastern Slovakia shows the complete succession of Lower Jurassic to Upper Jurassic (Oxfordian) deposits well dated by ammonite faunas. The Lower Jurassic includes: sandstones and sandy marls (Dolný Mlyn Fm., ?Hettangian - Early Sinemurian), spotty limestones and marls (Allgäu Fm., Late Sinemurian – Late Domerian), glauconitic sandstones nad marlstones (Hôrka Fm. - new formation, Late Domerian), red marls (Hŕbok Marl Fm. – new formation, Toarcian). The Middle Jurassic part of the succession comprises thick crinoidal limestone formation (Aalenian - Bajocian) informally subdivided into three members: Member A - alternation of marly crinoidal limestones and grey marls, Member B - reddish crinoidal limestones, partly nodular, with intercalations of red nodular micritic limestones and cherts, Member C - greenish and grey crinoidal limestones with black cherts. These deposits are abruptly overlain along a marked ommission surface by pelagic ammonitico-rosso type limestones of the Czorsztyn Limestone Fm. (Late Bajocian – Oxfordian). The limestones are developed as filamentous microfacies of the latest Bajocian to early Bathonian age and followed by the *Globuligerina* microfacies yielding ammonites of Oxfordian age.

The Lower Cretaceous part of the succession corresponds to the Nižná Fm. It consists of various deposits such as crinoidal limestones, synsedimentary limestone breccia and marls containing abundant organodetrital material of the Urgonian shallow-water carbonate platform origin.

The succession of the Beňatina Klippe differs from typical successions of the Pieniny Klippen Basin. It may be interpreted either as a variety of the Czorsztyn Succession, and thus located in the northern part of the basin, or even as succession deposited at southern margin of the Pieniny Klippen Basin. Some ammonites of Early Jurassic to early Middle Jurassic so far poorly known from the West Carpathians are described in the palaeontological part of the paper. These include representatives of Lytoceratidae (*Alocolytoceras*), Arietitidae (*Coroniceras*), Hildoceratidae (*Frechiella*) and Graphoceratidae (*Ludwigia*, *Graphoceras*, *Brasilia*).

Key words: Jurassic, Western Carpathians, Pieniny Klippen Belt, Lower Cretaceous, ammonites

Introduction

Latest geological research in Eastern Slovakian part of the Pieniny Klippen Belt (PKB) brought new and important information on lithostratigraphic variability, paleontology and biostratigraphy of the Jurassic and Early Cretaceous deposits of this complex zone. The area of the PKB was affected by two tectonic phases which caused its breakage into separated "klippen", completely detached from their basement and from the neigbouring units as well. Therefore, the palaeogeographic reconstructions are based on the facies development of the individual klippen. Importance of the studied Beňatina Klippe lies in several levels. The locality represents one of the rare places with well preserved Liassic deposits. Moreover, some lithostratigraphic units in this klippe are new or show development different from that of the classic sections. The deposits exposed at Beňatina Klippe are rather highly fossiliferous, enabling their detailed biostratigraphic interpretation. In addition, the Middle Jurassic ammonite fauna occurring here shows a presence of some exotic South-Tethyan taxa, until now completely unknown from the Alpine-Carpathian areas (Schlögl & Rakús, in press).

The Beňatina Klippe belongs to the easternmost Slovak part of the Pieniny Klippen Belt (Fig. 1), situated on the NE edge of the Vihorlat Mountains, between the Diel Stratovolcano to the West and the Popriečny Stratovolcano to the East. These consist of young, Neogene volcanics which cover Jurassic-Cretaceous klippen of the PKB, except those in the vicinity of the villages Podhorod' and Beňatina. Almost all the deposits exposed in the klippen have been treated as belonging to the Czorsztyn Succession, with overall stratigraphic range in

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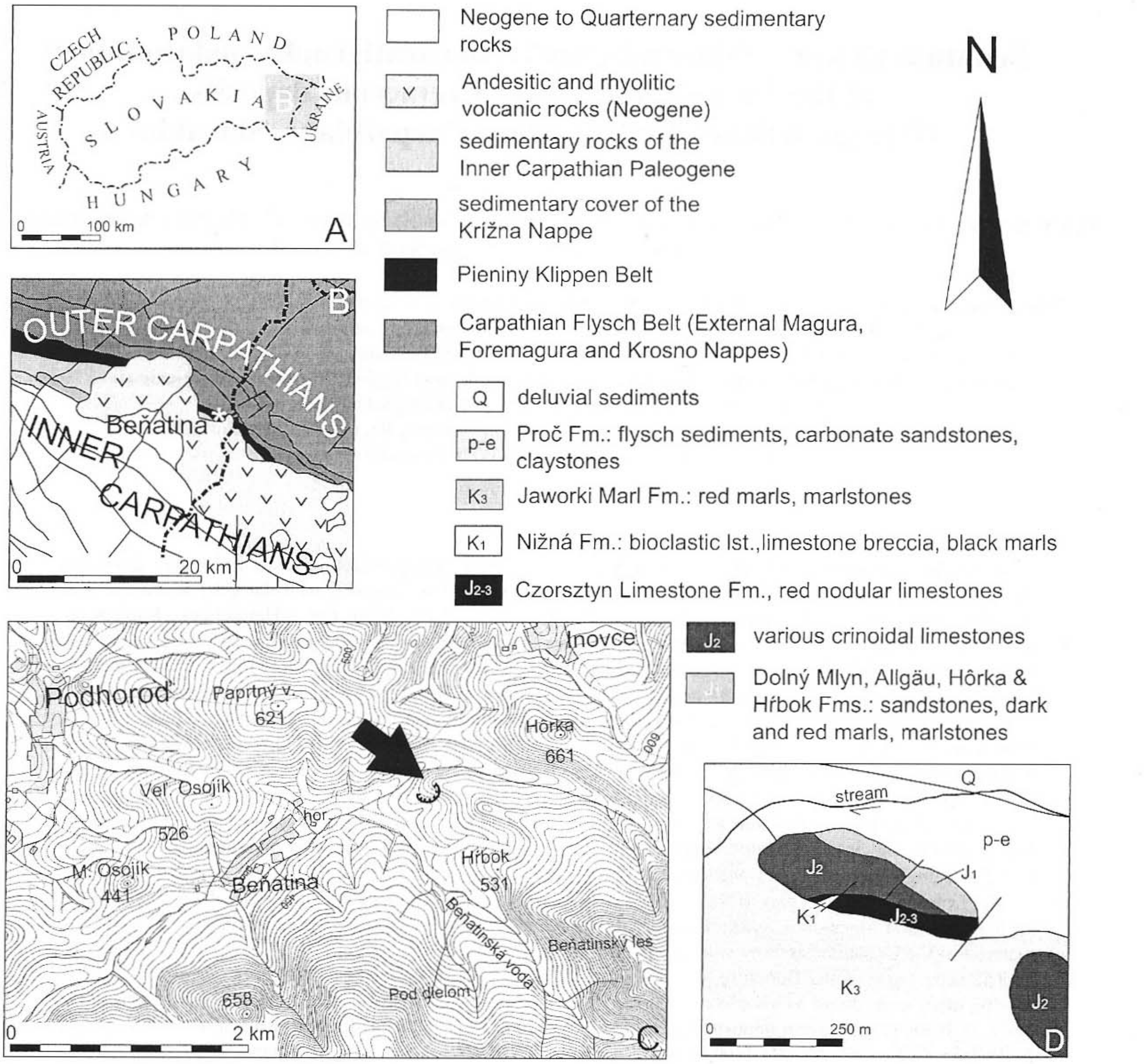

Fig. 1. Geographical and geological setting of the Beňatina klippe. A, C. Geographical position of the area of study (the quarry is arrowed). B. Geological sketch map of the eastern part of PKB and adjacent areas. D. Simplified geological map of the Beňatina klippe (after the manuscript of M. R.).

the studied area from the Hettangian to the Late Maastrichtian (Rakús & Potfaj, 1997). Three sections have been studied by the present authors in the Jurassic part of the succession in the quarry worked of the Beňatina Klippe: one in the northeastern part of the quarry (Fig. 2, denoted here as Section I, see also Figs 4.1-2), another in the western part of the quarry (Fig. 2, denoted as Section II), and the third in the southeastern part (Fig. 2, denoted as Section III). Moreover the Lower Cretaceous deposits were studied in the southwestern part of the quarry (Fig. 3 and Fig. 6.1, denoted as Section IV), but their relation to the deposits from Sections I-III is somewhat unclear.

Lithostratigraphic succession at the Beňatina quarry

Dolný Mlyn Formation

This formation was formerly well exposed in the upper northeastern part of the quarry (Fig. 4.1-2); recently, this face of the quarry is mostly obscured. Sandstones with thin intercalations of greenish marls prevail in the lower part of the formation. At the base there is 3 to 5 metres thick complex of light grey (brown on weathered surfaces) thin-bedded (layers to 10 cm), fine-grained sandstones and greenish sandy marls (Fig. 2). Sandstone "concretions" with limonitic crusts occur in thicker layers. Towards the top, the sandstones become more calcareous. They are commonly rich in opaque Fe cement. The sand grains are mostly represented by quartz, with very rare glauconitic grains, biotite scales and tiny echinoderm ossicles (Fig. 5.1). The sand is of nearly uniform size and very well sorted. The grains are subangular to angular. The opaque cement obviously migrated through the pore spaces subparallel with bedding and omitting more lithified parts of the sandstone. Locally, tiny elongated voids filled with chalcedony occur in the sediment.

The lower "sandstone" part is succeeded by dark-grey marls and marly limestones with coquina layers.

These are essentially represented by oysters (*Liogryphaea* layer, see section I). A 20 cm thick dark grey bioclastic limestone bed, lying directly below this coquina, yielded bivalves, gastropods, indeterminable fragments of arietitid ammonites and small clusters of serpulid tubes. A 20 cm thick dark grey marly limestone, lying above the *Liogryphaea* coquina, yielded a rich brachiopod fauna. It is bioturbated wackestone with irregular distribution of allochems. The matrix is partly recrystallized to peculiar microsparite with needle-shaped calcite crystals. These fibrous crystals locally perpendicularly overgrow some allochems. The allochems are represented by bivalve and brachiopod shell debris, agglutinated foraminifers *Ophthalmidium* sp., nodosariid foraminifers, less commonly - ostracods, echinoid spines and rarely - thin serpulid tubes. The sediment commonly contains framboids and seams of pyrite. Pyrite also locally infills the foraminiferal tests.

The upper part of the Dolný Mlyn Formation consists of a few metres thick complex of dark grey to black, more or less calcareous, slightly sandy marls with 10 to 35 cm thick layers of spotty marly limestones occuring mainly in its uppermost part (Fig. 2). These wackestones are rich in echinoderm ossicles, ostracods, fragments of juvenile bivalves, spicules, nodosariid foraminifers and plant fragments. Syngenetic pyrite is common, sometimes filling up the internal parts of ammonites.

Ammonite fauna was collected from the marly limestone beds from the uppermost part of the formation. It consists of arietitid taxa, such as *Coroniceras lyra* Hyatt or *C.* (*Paracoroniceras*) cf. *charlesi* Donovan and numerous *Arnioceras* sp. and *Arnioceras semicostatum* (Young & Bird) (*Arnioceras* are ex situ). Because of tectonics, the overall thickness of the formation cannot be measured.

Allgäu Formation

The overlying part of the sequence shows light-grey marly, sometimes spotty limestones alternating with grey-bluish to grey marls, called Allgäu Formation. Its overall thickness is not measurable, the uncovered part attains 14 metres. In the NE part of the quarry the formation is probably tectonicaly reduced (Fig. 2). Upper part of this formation is also visible at the entrance to the quarry, in its western part (Section II).

Macroscopic observations show that the sediment is spotted, i.e. bioturbated. This is not visible in the thin-sections. It is biomicrite, packstone with tiny detritus of mostly indeterminable allochems, which are mainly represented by sponge spicules, nodosariid foraminifers, echinoderm ossicles and tests of ostracods. Silty quartz admixture is present, too. Locally, seams and clusters of pyrite occur in the sediment.

Formation yielded numerous belemnite guards and ammonites: *Partschiceras* cf. *striatocostatum* (Meneghini), ?*Juraphyllites* sp., *Androgynoceras* sp., ?*Liparoceras* sp., *Pleuroceras* cf. *solare* (Phillips), *Pleuroceras* cf. *spinatum* (Bruguière), as well as badly preserved dactylioceratids such as ?*Reynesoceras* sp. and *Dactylioceras* sp. (cf. *D.* (*Orthodactylites*) *mirabilis* Fucini).

Hôrka Formation, new lithostratigraphic unit

Thin complex of greenish glauconitic sandstones, dark grey to greenish sandy-crinoidal limestones and glauconitic marlstones with intercalations of dark-green marls occurs between the underlying Allgaü Fm. and the overlying Hŕbok Marl Fm. (Fig. 2, Fig. 4.1-3). From the microfacies point of view they are biomicrites, wackestones to packstones with commonly occurring echinoderm ossicles, detritus of various bivalves (including thin-shelled "filaments"), ostracods, rare echinoid spines and nodosariid foraminifers. The rocks show the presence of the pressure seams with concentrated clay minerals and newly formed short fibrous calcite in the pressure shadows. Some layers (e.g. uppermost layer) are rich in juvenile ammonites. Ammonite shells are commonly geopetally filled. In some instances, these infillings do not correspond to each other which indicates some reworking of the sediment.

At the upper surfaces of the highest two beds there were found numerous Fe-oncoids and pyrite framboids, indicating stronger condensation and/or stratigraphic hiatus.

The formation yielded poor ammonite fauna including *Dactylioceras* sp. (cf. (*Orthdactylites*) *mirabilis* Fucini) and badly preserved fragment of an harpoceratid ammonite (*Lioceratoides*).

We introduce the name Hôrka Formation for this new lithological unit. The name is inferred from the hill Hôrka in the close neighbourhood of the Beňatina quarry (Fig. 1C). The overall thickness of the formation is 3.2 m in the section I. and 2.5 m in the section II.

Hŕbok Marl Formation, new lithostratigraphic unit

This striking new unit consists of red, locally laminated marls with aligned small concretions and rare thin intercalations of sandy marlstones up to 4 cm in thickness (Fig. 2). They represent biomicrites, wackestone to packstones (Fig. 5.3-8). Thin-shelled bivalves (*Bositra* sp.) dominate among the allochems (Fig. 5.5); moreover, there occur calcified sponge spicules, echinoderm ossicles, ostracodes, nodosariid foraminifers, *Lenticulina* sp., *Spirillina* sp., as well as the juvenile gastropods and fragments of the brachiopod shells. The allochems are often impregnated by Fe-Mn opaque minerals. A thin marlstone layer with abundant small ammonites has been observed in the lowermost part of the section (Fig. 5.8).

Some layers in the middle and upper part of the formation contain numerous small concretions (up to 3-4 cm in diameter) with Fe-Mn encrustations (Fig. 5.6). Round intraclasts of lithified sediment impregnated by Fe-Mn oxides form core of these concretions. Their impregnation is irregular; being more expressed at the margins, where the intraclasts are coated by thin microbial stromatolites. Inside the intraclast, the Fe-Mn impregnation is shown by irregular concentric seams. The sediment itself is represented by "filament" packstone to wackestone. Along with "filaments" (thin shells of *Bositra* sp.), the sediment contains common *Lenticulina* sp.,

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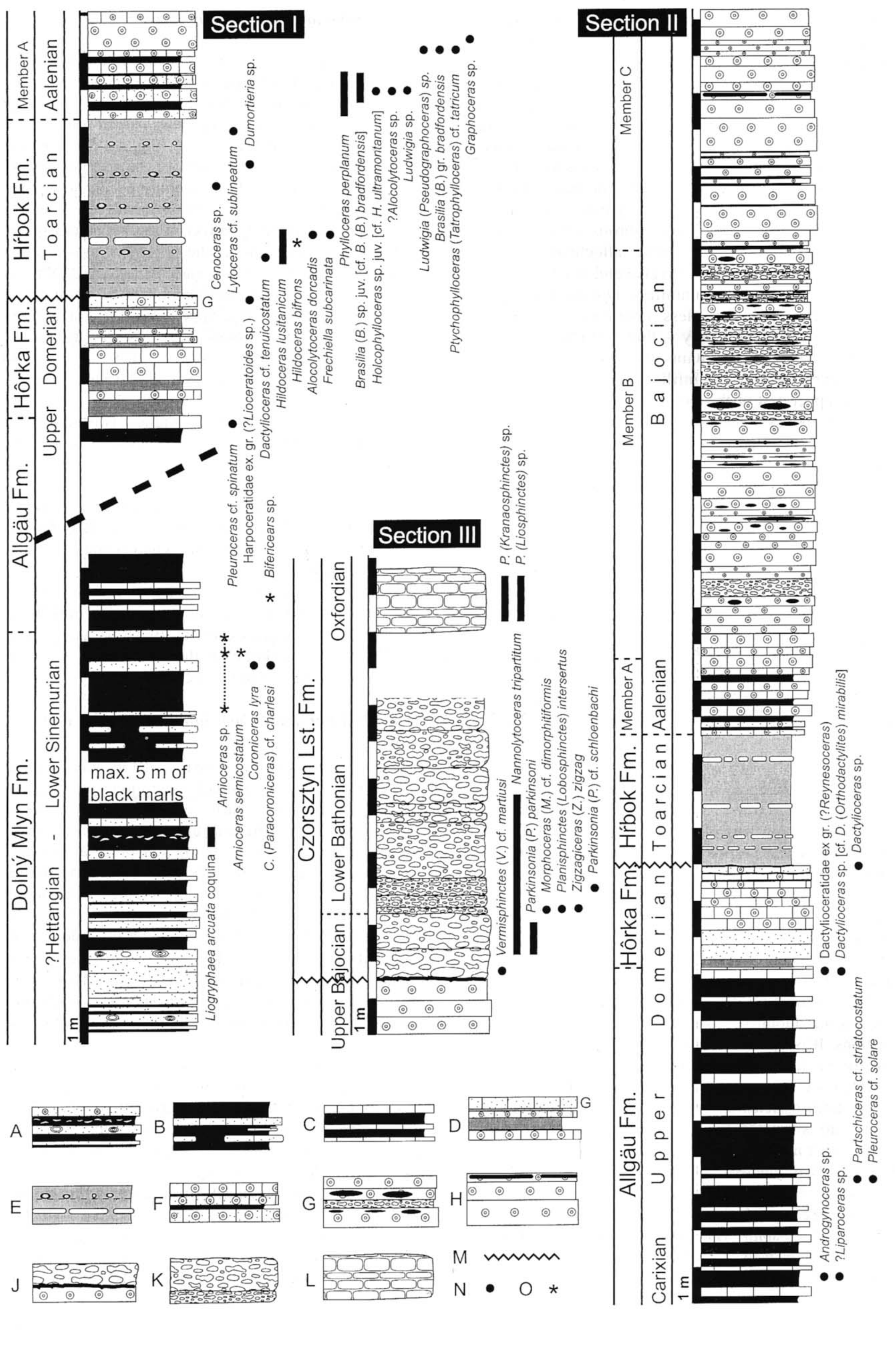

nodosariid foraminifers, shells of ostracods and rare echinoderm ossicles.

The macrofossils include fairly common belemnite guards, and rather rare ammonites. The lower part of the Hŕbok Marl Formation yielded several fragmented dactylioceratid ammonites, whereas its middle part yielded *Alocolytoceras dorcadis* (Meneghini), *Frechiella subcarinata* (Young & Bird), *Hildoceras bifrons* (Bruguière) and *Hildoceras lusitanicum* Meister. Rare fragments of grammoceratid ammonites, *Lytoceras* cf. *sublineatum* (Oppel) and *Cenoceras* sp. were collected from the upper part of the formation.

We introduce the name Hŕbok Marl Formation for this new lithological unit. The name is derived from the hill Hŕbok in the close neighbourhood of the Beňatina quarry. The formation reaches 5 m in thickness in the section I, but it is only 3.6 m thick in the section II.

Formation of variable crinoidal limestones

The main part of the sequence is built by huge mass of crinoidal limestones (40 m at least). On the base of their variable lithology we have distinguished three different crinoidal complexes (members) within this formation, developing gradually one from another (Fig. 4.1,4,6).

The lower part (Member A) is represented by alternations of light grey marly crinoidal limestones and grey marls, rich in crinoidal ossicles. They develop gradually from the underlying deposits of the Hŕbok Marl Fm. (Fig. 4.1-2). Upward they continue as grey, locally always slightly marly crinoidal limestones. Abundant fauna of small phosphatized ammonites was found in the marly crinoidal limestone beds. The ammonites were probably reworked from the marly intercalations as suggested by theirs common presence within the marly intraclasts. Among the ammonites, *Phylloceras perplanum* Prinz, *Holcophylloceras* sp. juv. [cf. *H. ultramontanum* (Zittel)], ?*Alocolytoceras* sp., *Ludwigia* sp., *Brasilia* sp. juv. [cf. *B. (B.)* gr. *bradfordensis* (Buckman)], were recognized. Grey, always slightly marly crinoidal limestones and creamy (yellowish) crinoidal limestones from the upper part of the member are also rich in ammonites, essentially phylloceratids *Ptychophylloceras* (*Tatrophylloceras*) cf. *tatricum* (Pusch), and graphoceratids: *Ludwigia* (*Pseudographoceras*) sp., *Brasilia* (*Brasilia*) cf. *bradfordensis* (Buckman) and *Graphoceras* sp. In this part, fragments of coalified wood and one large (30 cm) fragment of black biotitic mica-schist were found.

From the microfacies point of view the deposits are sandy crinoidal biomicrites, packstones. The sandy admixture is mainly represented by angular quartz reaching up to pebble size. Other clasts belong to dolomites and siltstones. The bigger quartz grains show undulosity and polycrystallinity. Besides the crinoidal ossicles, nodosariid foraminifers, *Lenticulina* sp. and various sorts of bivalve and brachiopod shells, echinoid spines, bryozoans and various agglutinated foraminifers are present. The allochems are commonly bored, with the borings filled by Fe-Mn opaque minerals. These minerals also form clusters and seams within the sediment.

The middle part of the crinoidal limestone sequence (Member B) shows a great complexity, with alternation of different facies types (Fig. 2). Thick bedded reddish crinoidal packstones, with brown to dark red cherts, are typical for the lower 4 metres. Some beds are richer in clastic quartz. Reddish to greenish thick-bedded crinoidal packstones, with red cherts and intercalations of nodular limestone, follow in the next 6 metres (Fig. 4.5). Some beds are composite, with red micritic nodules in crinoidal matrix in the lower part of the layer and crinoidal packstone in its upper part. Except of some disarticulated brachiopods no macrofauna was found here. The crinoidal packstones are frequently silicified. The only preserved allochems are echinoderm ossicles, bivalves, brachiopods, foraminifers *Lenticulina* sp. and rare echinoid spines. Allochems are surrounded by chalcedony, locally with preserved remnants of the original intergranular micrite.

The upper part of the formation (Member C) is characterized by change of limestone colour from reddish to greenish and grey/greenish and absence of nodular or nodular/crinoidal layers and red cherts (Fig. 4.6). The limestones become coarser and thick-bedded (up to 1 m); the beds are frequently separated by thin layers of green marls or marlstones. They usually have a character of crinoidal packstones, but locally also of grainstones. Principal allochems as crinoidal particles are size-sorted. Filaments, juvenile gastropods and benthic foraminifers are common. Clastic admixture varies from 1 to 10%. It is dominated by quartz grains, abundant lithoclasts and rare glauconite grains. Dark grey to black stratiform cherts are present in the upper part of the member. Due to tectonics, the overall thickness of this sequence is not mesurable, but it is 30 metres thick at least. The sequence is capped by a thin Fe/Mn crust.

Czorsztyn Limestone Formation

Ammonitico Rosso deposits of the Czorsztyn Limestone Formation built almost the entire southern face of the quarry (Fig. 4.7). The formation was studied in detail by Rakús (1990a) and Schlögl (2002). The first 20 cm of the formation have a character of pseudonodular limestone, containing dispersed crinoidal detritus in nodules

Fig. 2. Jurassic of the Beňatina quarry. Section I. NE face of the quarry. Section II. Left side of the quarry entry. Section III. SE face of the quarry.
A. sandstones, crinoidal sandy limestones, dark shales with Liogryphaea arcuata coquina. B. dark marls with intercalations of dark-grey silty marlstones. C. dark to grey-greenish marls with marlstone layers. D. crinoidal marly limestones, sandstones with glauconite (G), greenish marls. E. red marls with marlstone layers and encrusted concretions. F. crinoidal marly limestones, dark-grey crinoidal marls. G. red crinoidal limestones with red cherts and nodular layers. H. cream to yellowish crinoidal limestones with black cherts. J. mineralized hardground between crinoidal and nodular limestones. K. red and grey nodular limestones. L. pseudonodular limestones. M. main omission surfaces and hard-grounds. N. fauna collected in situ. O. fauna collected ex situ.

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and in surrounding matrix as well (crinoidal-filamentous wackestone and packstone). Coarse grains of quartz, traces of bioturbation and reworked ammonites occur near the base of the formation. Clastic admixture rapidly decreases upward. The ammonite casts are oriented parallel to the bedding. Ammonite fauna comes from the next 2 metres, including almost exclusively large specimens of *Parkinsonia (P.) parkinsoni* (Sowerby).

In the next 5 metres the limestones are richer in marly matrix, and the nodules are smaller (up to 5 cm). Mineralized intraclasts are common (intraclastic nodular facies, sensu Savary, 2000, Cecca et al., 2001). The ammonites are very abundant. In majority, they are fragmented with coroded upper sides and randomly placed in the beds.

The whole visible part of the formation consists of wackestones to packstones with "filamentous" microfacies and numerous mineralized intraclasts. Except the thin-shelled bivalves the allochems include calcified radiolarians, *Globochaete* sp., echinoderm ossicles and benthic foraminifers. Juvenile gastropods and sponge spicules appear locally in some beds.

Still younger deposits are preserved only as loose blocks in the floor of the quarry. These are pseudonodular limestones very poor in marly matrix. Nodules are large and irregular, composed of wackestones with *Globuligerina* microfacies. Only a few badly preserved fragments of perisphinctid ammonites were found here: *Perisphinctes (Kranaosphinctes, Liosphinctes)* spp.

Nižná Formation

These deposits form few metres thick sequence in the SW part of the quarry (Fig. 3, Fig. 6.1). The full thickness of the deposits remains unknown. The deposits are in tectonic contact with nodular limestones of the Czorsztyn Limestone Formation. This variable sequence consists of thin beds (up to 30 cm) of grey organodetrital (mostly echinoderm) limestones, black marls, grey siliceous limestones and limestones with laminated cherts. Two beds also contain silicified wood fragments (Fig. 6.3), locally mixed with chert debris. On the basis of the lithological variability, the formation can be subdivided into four units:

1. Creamy to grey, fine-grained crinoidal limestones with glauconite. These 150 cm thick thin-bedded limestones are free of lithoclasts or quartz admixture (Fig. 6.6). Locally, the limestones are laminated, sometimes silicified.

2. Coarse crinoidal limestone rich in lithoclasts of green, white and pink micritic limestones with some admixture of micritic clasts with glauconite and green micritic clasts with grey cherts. The lithoclasts are rounded, not sorted by size (Fig. 6.5,7). Some bigger lithoclasts are frequently bored (macroborings). The bed is 55 cm thick

3. Grey bedded limestones with cherts and wood fragments. They begin with 20 cm thick allodapic layer of beige, fine-grained limestone with hummocky cross-stratification. Next allodapic layer (30 cm thick) is separated by thin 5 cm thick black marl. This layer contains thin laminated cherts and coalified and silicified wood fragments (Fig. 6.3, Fig. 11). Next 30 cm thick crinoidal limestone layer shows an erosive base: it is laminated in the lower part but becoming massive and structureless towards the top; small lithoclasts and glauconite grains are common. Still higher layer, 5 to 8 cm thick, is the chert layer with wood fragments. Some wood fragments are 10-20 cm long and bear traces of *Teredo*-type borings filled with sediment (Fig. 6.4). The topmost layer of the unit consists of two parts: the lower part is represented by fine-grained, grey, massive crinoidal limestone, whereas the upper part consists of more fine-grained, indistinctly laminated crinoidal limestone with black cherts and dark grey bioturbated marls.

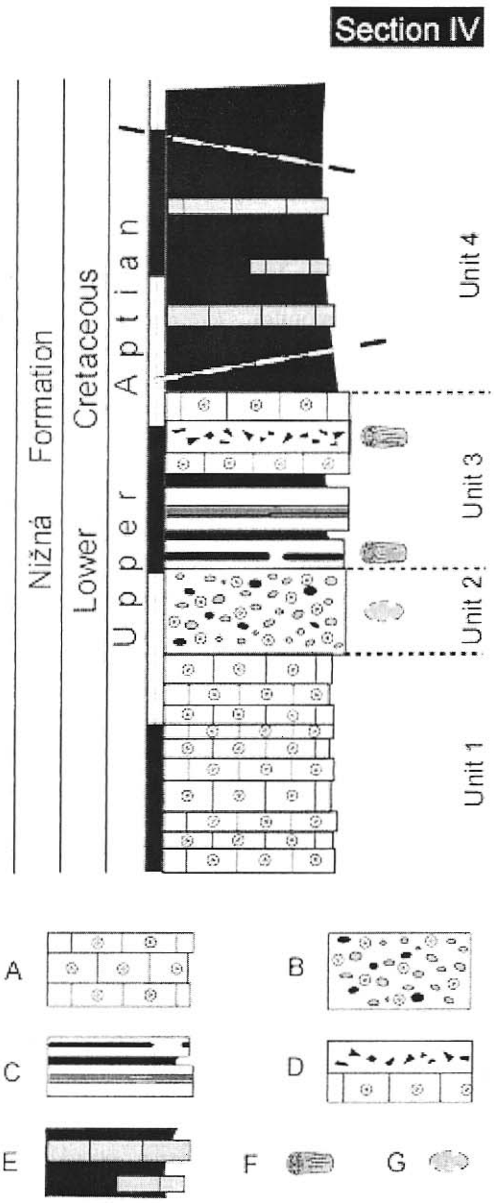

Fig. 3. Lower Cretaceous of the Beňatina quarry. Section IV. The toe of the SW face of the quarry.
A. creamy to grey crinoidal limestones. B. crinoidal limestone with numerous lithoclasts (breccia). C. grey biodetritic limestones with black cherts (locally laminated), black marls. D. grey detritic/crinoidal limestone with chert fragments. E. black marls with marly limestone layers and concretions. F. fossil wood fragments. G. lithoclasts with macroborings.

The limestones of the unit 3 have a character of biomicrites, packstones with skeletal detritus and various clasts. Some bioclasts point to shallow water origin of a part of detritus at least. The limestone contains numerous echinoderm ossicles (including complete crinoid calices), coralline algae, big orbitolinid foraminifers, thick layered tubes of serpulid worms, detritus of oyster-type shells, inoceramid shells, punctate brachiopods, bryozoans and agglutinated foraminifers. The intraclasts are mostly represented by marlstones, packstones with hedbergellid foraminifers or with rhaxa. Some clasts are phosphatized. The phosphatization prograded from inside, the outer parts of the clasts remained unchanged. One of the clasts is coated by thin phosphatic stromatolite, forming thus an initial oncoid. Along with hedbergellid foraminifers, the clasts contain agglutinated foraminifers, and prisms of inoceramid shells. There is also a large biosparitic clast with mostly indeterminable micritized allochems, agglutinated foraminifers, hedbergelids, fragments of bivalve shells and echinoderm ossicles. Some clasts with sponge rhaxa microfacies were observed too.

4. Bioturbated, black to dark green marls and marlstones (locally with pale laminae) with disturbed layers of dark limestones. In a pale laminae there are marls with dispersed larger allochems, e.g. echinoderm ossicles, detritus of oyster-type bivalves and agglutinated foraminifers. The laminae also contain silty quartz admixture, rare glauconite grains and intraclasts of organodetrital carbonates to marlstones (with coralline algae). The dark bioturbated marlstone contains tiny allochems, mostly indeterminable detritus of various skeletal organisms (Fig. 6.8). Only ostracod shells, poorly preserved hedbergellid foraminifers, rare phosphatic bone detritus, foraminifers *Lenticulina* sp. and agglutinated foraminifers could be determined. Like in the pale laminae, the sediment contains silty quartz admixture.

Biostratigraphy

Generally, the studied succession at Beňatina is sufficiently rich in macrofossils, enabling recognition of the chronostratigraphical ranges of the bulk of the lithostratigraphical units.

Dolný Mlyn Formation *(?Hettangian – Early Sinemurian)*

The lower, "sandstone" part of the formation has yielded a scarse biostratigraphicaly valuable macrofauna only. Rich brachiopod fauna collected from the marly limestone layer (directly above the oyster coquina, see Fig. 2, Section I) is represented mainly by *Callospiriferina haueri* (Suess) and *Liospiriferina* cf. *pichleri* (Neumayr), and by a few representatives of *Cirpa* aff. *planifrons* (Ormos) and *Calcirhynchia* cf. *fascicostata* (Uhlig). This fauna indicates early Liassic age of this dark grey limestones and suggests Hettangian or Early Sinemurian age as based mainly on biostratigraphical value of the first mentioned species known from the gresten facies of the Northern Calcareous Alps (e.g. Siblík, 1999). This taxon is very close to the most typical Early Jurassic Alpine spiriferinids – *Callospiriferina tumida* (Buch) and *Liospiriferina alpina* (Oppel) (Siblík, 1993, Dulai, 2003). A big undeterminable fragment of arietitid ammonite has been collected from the same bed indicating probably Early Sinemurian age. Moreover, the presence of coquina with *Liogryphaea arcuata* (Lamarck) confirms this datation, the stratigraphical range of the species being stated as Hettangian to Early Sinemurian.

On the other hand, rich ammonite fauna has been found in the upper, "marly" part of the formation. The topmost layers of the formation yield *Coroniceras lyra* Hyatt (Fig. 7.4, 8.3) and *C. (Paracoroniceras)* cf. *charlesi* Donovan (Fig. 8.2). They indicate the *A. semicostatum* Zone of the Early Sinemurian. Moreover, numerous *Arnioceras* sp. (Fig. 8.6) and *Arnioceras semicostatum* (Young & Bird) (Fig. 8.4) collected in the rubble, indicate the same stratigraphic interval.

Allgäu Formation *(Late Sinemurian – Pliensbachian)*

Ammonite fauna was collected mainly from the marly limestone beds. The oldest ammonite fauna originates from the rubble below the section I, including a small fragment of *Bifericeras* sp., a taxon characteristic of the Late Sinemurian *O. oxynotum* Zone. Very poorly preserved ammonites, including *Androgynoceras* sp. and ?*Liparoceras* sp. come from the lowermost exposed bed in the section II. These taxa are already indicative of the Carixian. Next fauna occurs approx. 3 m higher. It includes *Partschiceras* cf. *striatocostatum* (Meneghini) and, especially, *Pleuroceras* cf. *solare* (Phillips) (Fig. 9.4) that prove the Late Domerian age (*P. spinatum* Zone). The presence of *Pleuroceras* cf. *spinatum* (Bruguière) (Fig. 9.5) at the upper boundary of the formation indicates also the Late Domerian age. The latter form is associated with ?*Reynesoceras* sp. and with dactylioceratid ammonites *Dactylioceras* sp. (cf. *D. (Orthodactylites) mirabilis* Fucini). These *Dactylioceras* demonstrate dense ribbing with typical annulate ribs, a character shown by the earliest representantives of the genus. Their occurrence was recently stated in upper *P. spinatum* Zone of the Late Domerian (Rakús, 1995).

Hôrka Formation, new unit *(Late Domerian)*

Only uppermost beds yielded stratigraphicaly valuable ammonites. The co-occurrence of very badly preserved Harpoceratidae, probably representing genus *Lioceratoides* and the primitive first *Dactylioceras* with annulate ribs (Fig. 9.2), indicates Late Domerian age.

Hŕbok Marl Formation, new unit *(Toarcian)*

The ammonite fauna is not abundant but very significant, covering the whole Toarcian. The Early Toarcian age for the lower part of the Hŕbok Marl Formation is proved by occurrence of *Dactylioceras* cf. *tenuicostatum* (Young & Bird) (Fig. 9.1), the index fossil of the *D. tenuicostatum* Zone. Numerous *Hildoceras lusitanicum* Meister, associated with *Hildoceras bifrons* (Bruguière) (Fig. 9.6, 9.7), as well as a rare ammonite *Frechiella sub-*

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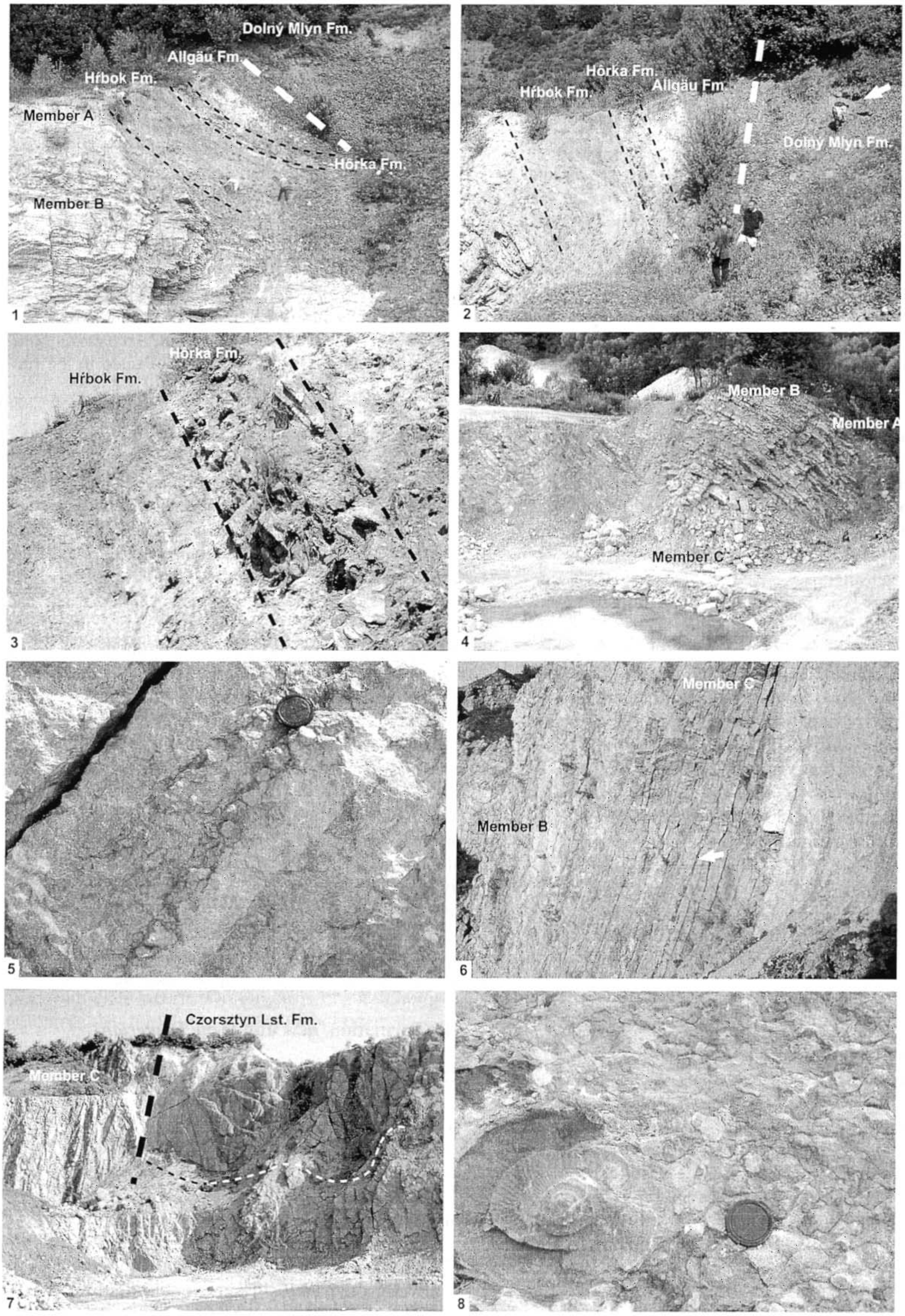

Fig. 4. 1-2. NE face of the quarry with the Liassic – Lower Dogger part of the section. 3. Detail of the boundary between Hôrka and Hŕbok Marl Fms. 4. Members A, B, C of the crinoidal limestone complex. 5. Detail of the reddish crinoidal limestone with red micritic nodules (Member B). 6. Upper part of the Member C, white to yellowish bedded crinoidal limestones with dark cherts (arrowed). 7. Tectonic (black line) and sedimentologic (black & white line) contact between member C and Czorsztyn Lst. Fm. 8. Detail of the Late Bajocian ammonitico rosso deposits of the Czorsztyn Lst. Fm.

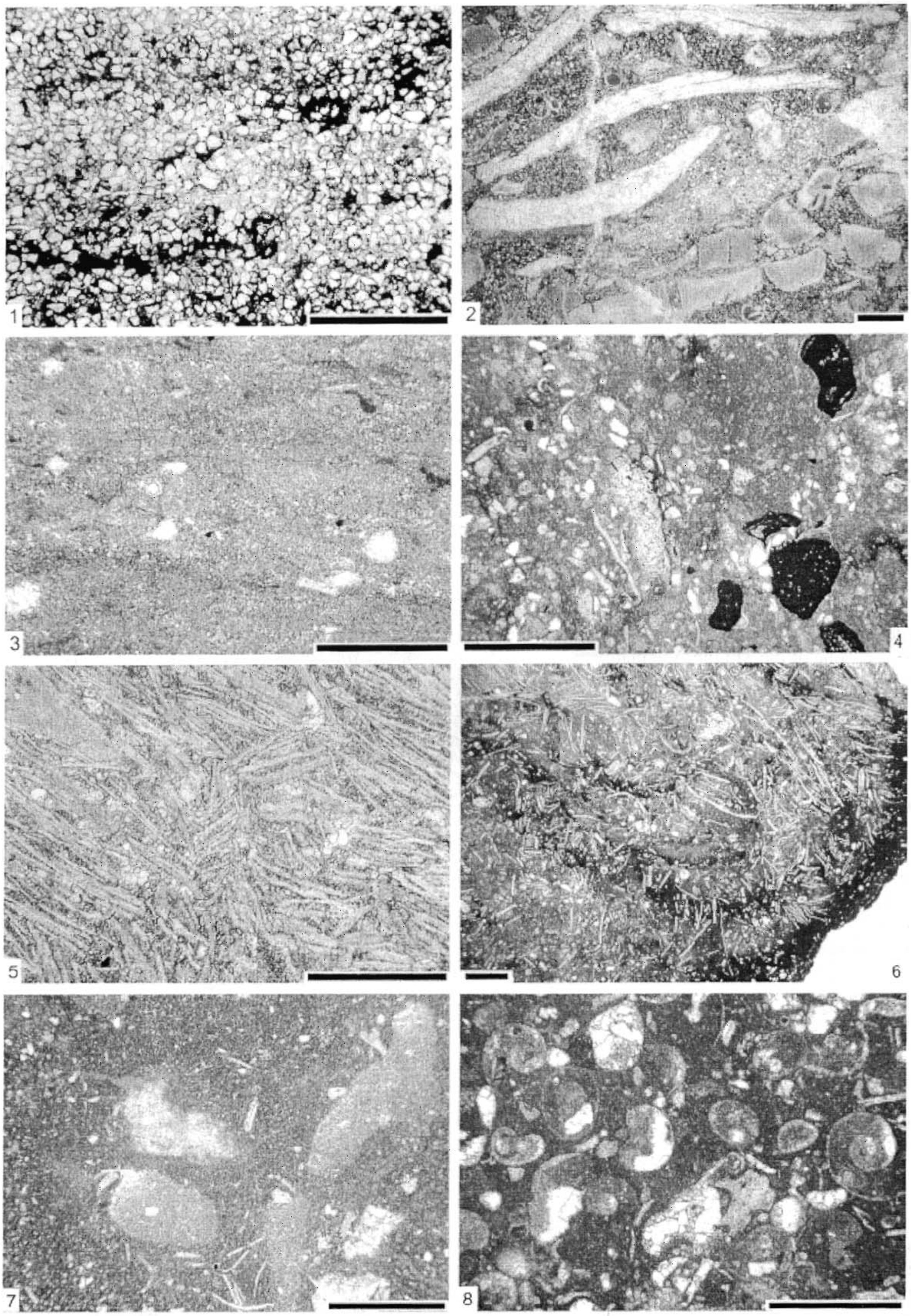

Fig. 5. 1. Dolný Mlyn Fm., sandstone with high portion of opaque cement in the intergranular space. 2. Dolný Mlyn Fm. (lowermost uncovered layer, Section I), crinoidal paskstone with large isolated crinoidal ossicles and numerous oyster fragments. 3-8. Hŕbok Marl Fm.: 3. Red marls. 4. Wackestones with numerous mineralized lithoclasts and high portion of quartz grains. 5. Bositra coquina. 6. Fe-oncoid with filamentous wackestone as a core, enveloped by thin microbial crust. 7. Red marls, heavily bioturbated. 8. Ammonite coquina, the base of the Hŕbok Marl Fm. (Scale bar = 1 mm)

carinata (Yong & Bird) (Fig. 9.8), found in thin marlstone layers in the middle part of the formation prove the *H. bifrons* Zone of the Middle Toarcian. The occurrence of grammoceratid ammonites (*Dumortieria* sp.) in the upper part of the formation already suggest the Late Toarcian age. The uppermost layer of the red marls of the formation yields, moreover, *Lytoceras* cf. *sublineatum* (Oppel) (Fig. 8.1), the species frequently reported from the Middle–Late Toarcian (Schlegelmilch, 1976, Rulleau, 1998).

Crinoidal limestones
Member A *(Aalenian)*

There are two ammonite faunas recognised in this member. The lower, marly crinoidal limestones and crinoidal marls contain abundant small resedimented phosphatized ammonite casts. Phylloceratina highly prevail over Lytoceratina and Ammonitina, representing more than 90% of the whole fauna. The identified *Phylloceras perplanum* Prinz (Fig. 7.2), *Holcophylloceras* sp. juv. [cf. *H. ultramontanum* (Zittel)] (Fig. 7.3), ?*Alocolytoceras* sp. have too wide stratigraphic ranges, and thus are of minor stratigraphic importance. On the other hand, *Ludwigia* sp. (Fig. 9.10, 9.12), and *Brasilia (Brasilia)* sp. juv. [cf. *Brasilia bradfordensis* (Buckman)] (Fig. 9.9) prove the *L. murchisonae* Zone of the Middle Aalenian.

The overlying grey, slightly marly crinoidal limestone beds yielded *Ptychophylloceras (Tatrophylloceras)* cf. *tatricum* (Pusch), *L. (Pseudographoceras)* sp. (Fig. 9.14), *Brasilia* sp. and *Brasilia (Brasilia)* cf. *bradfordensis* (Buckman) (Fig. 9.11). This fauna still indicates the *L. murchisonae* Zone. Poorly preserved fragments of *Graphoceras* sp. (Fig. 9.13) from the overlying beds of the creamy crinodal limestone (transitional part between the members A and B) already indicate the Late Aalenian *G. concavum* Zone.

Members B and C *(Bajocian)*

No ammonites are known from this part of the formation. The age of the members B and C can be estimated as the Early to upper Late Bajocian, on the base of the ages of the underlying and overlying deposits.

Czorsztyn Limestone Formation
(Late Bajocian – Oxfordian)

The basal 20 cm of the formation shows signs of resedimentation with reworked ammonite fauna containing big perisphinctid ammonites such as *Leptosphinctes (L.)* sp. and *Vermisphinctes (V.)* cf. *martiusi* (d'Orbigny). These are usually assigned to *G. garantiana* or lower *P. parkinsoni* Zone - the *P. acris* Subzone (cf. Galácz, 1980, Fernández-López, 1985). The lower part of the formation yields typical Late Bajocian fauna, including mainly *Parkinsonia (P.) parkinsoni* (Sowerby) (Fig. 10.4), the index species of the *P. parkinsoni* Zone. The Upper Bajocian part is approx. 2 metres thick. Very rich fauna collected from the overlying beds includes *Nannolytoceras tripartitum* (Raspail), *Planisphinctes (Planisphinctes) tenuissimus* (Siemiradzki), *Planisphinctes (Lobosphinctes) intersertus* Buckman (Fig. 10.1), *Morphoceras (M.)* cf. *dimorphitiformis* (Sandoval) (Fig. 10.2), *Pseudodimorphinites pinguis* (de Grossouvre) and *Zigzagiceras (Z.) zigzag* (d'Orbigny) (Fig. 10.3). It is typical of the *Z. zigzag* Zone (*M. parvum* Subzone) of the Early Bathonian. The species *Parkinsonia (Parkinsonia)* cf. *schloenbachi* Schlippe from still younger bed already suggests the *M. macrescens* Subzone of the *Z. zigzag* Zone. The overlying beds of the lower part of the formation exposed in the section in the quarry do not yield any stratigraphically important fauna.

The blocks of pseudonodular limestone found on the floor of the quarry yielded a few poorly preserved perisphinctid ammonites. These include *Perisphinctes (Kranaosphinctes)* sp., and *P. (Liosphinctes)* sp. indicative of the Middle Oxfordian.

Nižná Formation *(Late Aptian)*

The age of the formation can be determined on the base of the planktic foraminifers only. The occurrence of *Globigerinelloides algerianus* Cushmann & Ten Dam (Fig. 6.2), associated with *Blefusciana* cf. *infracretacea* (Glaessner), *Blefusciana aptiana* (Bartenstein) and also *Hedbergella* sp. prove the Late Aptian age of the black marls of the unit 4 (Fig. 3). Here the planktic forms are rare and constitute <5% of the total number of microfauna. This consists mostly of benthic foraminifers *Gyroidina* sp., *Lenticulina* sp., *Gavelinella* sp. (the most abundant), and others such as *Dentalina* sp., *Marginulinopsis* sp. and *Lagena* sp. as well as rare smooth ostracods.

The matrix of the limestone breccia (Unit 2 - see Fig. 3) is very poor in planktic foraminifers. On the contrary some clasts found here can be recognized as the foraminiferal packstones with dominant planktic foraminifers of the Late Aptian age which suggests short time difference between sedimentation of the deposits and their reworking.

Discussion

The section studied of the Beňatina quarry differs markedly from typical successions of the Pieniny Klippen Basin well recognised in central and western parts of the Pieniny Klippen Belt in Slovakia and Poland (see e.g. Andrusov, 1945; Birkenmajer, 1977; Mišík, 1997).

The lowest deposits exposed in the section are sandstones with intercalations of marls and *Gryphea* coquinas. They represent the Dolný Mlyn Formation and are of (?)Hettangian to Early Sinemurian age. Still younger are marls and limestones of Fleckenmergel/Fleckenkalk type corresponding to the Allgäu Formation and representing time interval from Late Sinemurian to Domerian. Very similar stratigraphic succession is known from the southwestern Ukrainian sections, at Priborzhavskoye and Perechin (Krobicki et al., 2003, and earlier papers cited therein).

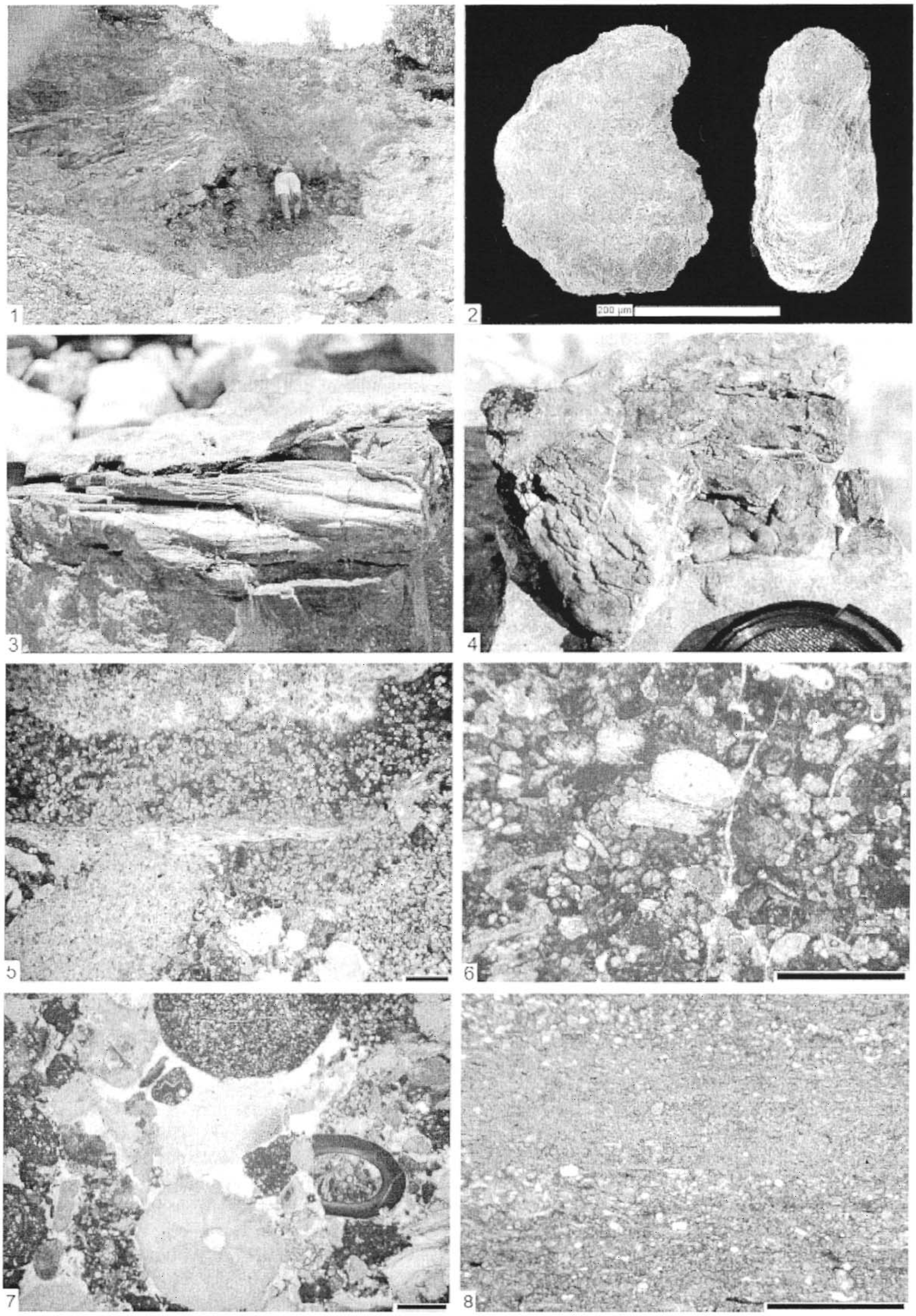

Fig. 6. 1-8. Nižná Unit: 1. Lower Cretaceous part of the Beňatina quarry. (backside of Michal Krobicki as a scale). 2. Globigerinelloides algerianus Cushman & Ten Dam, black marls of the Unit 4, Late Aptian. 3. Fossil wood fragment (approx. 15 cm long). 4. Teredo-like borings in the wood fragment. 5. Limestone breccia; the biggest clast (upper half of the picture) contains abundant planktic Late Aptian foraminifers. 6. wackestone with crinoidal particles, planktic foraminifers and bivalve fragments. 7. Limestone breccia consisting of rounded lithoclasts and large bioclasts (crinoid ossicles, serpulid tubes). 8. Laminated black shales. (Scale bars 5-8 = 1 mm)

The Lower Jurassic deposits corresponding to the discussed stratigraphical interval are generally poorly known in central and western parts of the Pieniny Klippen Belt. The Dolný Mlyn Formation has been known so far from a single section at the Dolný Mlyn quarry in western Slovakia (Rakús & Potfaj, 1997); the stratigraphical position of the spotty bituminous limestones and dark sandy marls representing there the upper part of the formation is documented (Hlôška, 1992) by occurrence of ammonite *Arnioceras mendax rariplicata* Fucini indicative of the Early Sinemurian. On the other hand, the deposits of the Allgäu Formation are known from not numerous sections in the Pieniny Klippen Belt in Poland and Slovakia where they yield ammonites of the Pliensbachian age (e.g. Andrusov, 1931; Birkenmajer & Myczyński, 1994; Rakús, 1995). These incomplete data make difficult the detailed recognition of the facies pattern in central and western part of the Pieniny Klippen Basin during Hettangian to Pliensbachian, and hence preclude closer palaeogeographical comparisons.

The stratigraphical interval at the turn from Lower to Middle Jurassic at the Beňatina quarry comprises three well marked lithological units. These include: green glauconitic sandstones, marls and sandy crinoidal limestones (Hôrka Formation, Late Domerian), red marls (Hŕbok Marl Fm., Toarcian), and marly crinoidal limestones and marls (Member A of crinoidal limestones, Aalenian). These units demonstrate small thicknesses, and other indications of slow sedimentation rate and/or synsedimentary erosion: presence of ferrugineous oncolites – directly below the Hŕbok Marl Fm., occurrence of intraclasts with thin microbial stromatolites and Fe-Mn encrustations – within the Hŕbok Marl Fm., rich admixture of clastic quartz grains, and presence of small phospatized ammonites in the clay lithoclasts – within crinoidal limestones of the member A. Similar lithology show deposits of uppermost Pliensbachian to Aalenian age in southwestern Ukrainian part of the Pieniny Klippen Belt at Priborzhavskoye and Perechin (see Krobicki et al., 2003). It is a development markedly different from coeval deposits of Toarcian to Aalenian age in central and western part of the Pieniny Klippen Belt in Slovakia and Poland. Here dominant are dark spotty limestones and marls (Krempachy Marl Formation) and dark marly shales with spherosiderite concretions (Skrzypny Shale Formation) well known from the Czorsztyn to the Kysuca/Branisko successions (see Birkenmajer, 1977).

A marked contrast between the two discussed areas was related possibly with uplift of the eastern segment of the Pieniny Klippen Basin already at the end of Lower Jurassic. Here, at Beňatina the sediments formed under anoxic-disoxic conditions (Dolný Mlyn Fm., Allgäu Fm.) were replaced at the turn of Pliensbachian and Toarcian by deposits formed in well oxygenated bottom conditions with clear signs of reworking of the sediment. The abrupt uplift, at the end of Lower Jurassic took place also in the area of North-Tatric Ridge south of the Pieniny Klippen Basin. It is distinguished as so called Devín Phase, marked by deep erosion, formation of extraclastic limestones, and an increasing contrast between the formation of partly anoxic sedimentation of the deposits of the Allgäu Fm., and appearance of well aerated "ammonitico-rosso" limestones of the Adnet Fm. (Plašienka, 2003). On the other hand, oxygen-depleted sedimentation continued during Toarcian and Aalenian in the bulk of central and western parts of the Pieniny Klippen Basin. It has been not earlier than during Early Bajocian when also in this area, the crinoidal limestones appeared what was related with uplift and formation of the Czorsztyn Swell (Ridge) (see Aubrecht et al., 1997).

The members B and C of the crinoidal limestones of the Beňatina sections show some similarities to the Flaki Limestone Formation of Birkenmajer (1977) from central and western parts of the Pieniny Klippen Belt. All these deposits contain some layers with chert nodules, and chert intercalations. However, the red or reddish to greenish colour of both limestones and cherts differs from grey or bluish colours of cherts typical of the Flaki Limestone Fm. Moreover, the nodular limestone intercalations recognized in the member B of the Beňatina section were never observed in the Flaki Limestone Fm. On the other hand, occasional silicification and nodular structures have been reported from the Smolegowa Limestone Fm, which is typical for the Czorsztyn Succession. However, the crinoidal limestones of the Smolegowa Limestone Fm. are generally grainstones, devoid of bedding or poorly bedded with characteristic high portion of detrital quartz and lithoclasts. The Flaki Limestone Fm. is known from central and western parts of the Pieniny Klippen Belt from successions deposited on the southern slope of the Czorsztyn Swell (Ridge) such as the Czertezik Succession and the Kysuca/Branisko Succession, but also from the Haligovce Succession which paleogeographical position is still debatable (see below).

The oldest deposits of the ammonitico-rosso type in the Beňatina section are developed as nodular limestones with variable amount of the marly matrix. They show the presence of the filament microfacies and yield ammonites of the latest Bajocian-Bathonian age. Still younger deposits found in loose blocks in the quarry, but very probably representing the same succession – are more massive, indistinctly nodular limestones of the *Globuligerina* microfacies of the Oxfordian age. There is undoubtedly a close similarity of the studied deposits in the Beňatina section to the Czorsztyn Limestone Formation well known from the Czorsztyn Succession of western and central parts of the Pieniny Klippen Belt (cf. Wierzbowski et al., 1999; Schlögl, 2002). The nodular limestones corresponding to the Czorsztyn Limestone Fm., and spanning the same stratigraphical interval, are known also from the areas located south of the Pieniny Klippen Basin, e.g. from the Manín Succession (e.g. Rakús, 1977). Although the detailed palaeogeographic position of the Haligovce-Manín Units within the Carpathians basins is still not fully cleared, they are placed either within the southern part of the Pieniny Klippen Basin (Haligovce Succession – after Birkenmajer, 1977) and in the neighbouring to the south – the so called Manín Basin (e.g. Andrusov, 1945, Rakús & Marschalko, 1997; Mišík, 1997), or even more to the south close to the High Tatra Succession (Plašienka, 2003).

Another problem remains palaeogeographical position of the Lower Cretaceous detritic deposits in the Beňatina section. The occurring here allodapic Urgonian deposits because of their unclear tectonic position cannot be considered with certainty as a part of the succession studied, although such a solution seems highly probable. They have only few equivalents in the Pieniny Klippen Basin – mostly in the Nižná Succession from the Orava part of Pieniny Klippen Belt in western Slovakia (Scheibner, 1967) where they are represented by grey, green-grey medium to coarse grained organodetrital gravel limestones, locally with cherts and fragments of carbonate rocks. Another locality with the Urgonian-like facies is the Haligovce Klippe, but palaeogeographical position of the Haligovce Succession is still doubtfull (see above). The principal difference between these two sections, and the Beňatina section lies in much more deeper character of the Nižná Succession and the Haligovce Succession where the Callovian-Oxfordian radiolarites and radiolarite limestones indicate their deposition below the CCD (like in deep-water Kysuca/Branisko Succession), whereas the Oxfordian red ammonitico-rosso deposits of Beňatina indicate more shallow environment.

Conclusions

The Beňatina quarry is a key locality for studies of the stratigraphy and palaeogeography of the eastern Slovakian part of the Pieniny Klippen Belt. Similar Lower and Middle Jurassic deposits are known also from the Priborzhavskoye and Perechin quarries in the Ukrainian part of the Pieniny Klippen Belt.

The correlation of this succession with other successions from the Pieniny Klippen Basin and the neighbouring areas presents, however, some problems, and it is interpreted in somewhat different manner by the particular authors. Some of us (J.S., M.R., M.K., R.A.) think that the overall development of Lower to Upper Jurassic deposits at Beňatina is typical for drowned platforms developed at the southern margin of the submarine Czorsztyn Swell (Czorsztyn Ridge). The presence of the crinoidal limestones in the Beňatina section in Toarcian and Aalenian probably indicates thus the earlier rising and breaking of the eastern segment of the Pieniny Klippen Basin. Although it is impossible to prove unequivocally that the Upper Aptian detrital limestones from the Beňatina quarry belong to the studied section, their occurrence could be considered as an indication of existence of Urgonian type of shallow-water sedimentation on the Czorsztyn Swell during Early Cretaceous. To distinguish different developments of deposits within the Czorsztyn Succession, Mišík (1997) and other authors usually used the term "variety". This leads us to propose the section of the Beňatina quarry as a new variety of the Czorsztyn Succession. Unlike the deeper-water units, the Czorsztyn Succession is characterized by great complexity and enormous facies variability, where no two localities show identical sections. The most characteristic feature of the Czorsztyn Succession, appears a total lack of the Callovian-Oxfordian radiolarites known mostly in other successions formed in the Pieniny Klippen Basin.

There is, however, possible another palaeogeographical interpretation of the Beňatina succession. The occurrence of deposits of Toarcian and Aaalenian age showing features indicating the reduced sedimentation rate may indicate closer relation of the succession studied with areas lying at southern margin of the Pieniny Klippen Basin. The same conclusions may be drawn from occurrence of the Urgonian type deposits which usually are known from the outer margin of the Inner Carpathians, from the carbonate platform zone developed in the Manín-High Tatric areas, or even at southern part of the Pieniny Klippen Basin. According to this interpretation preferred by two authors (B.A.M., A.W.), the studied section of the Beňatina quarry is the first known so far succession of southern origin within the eastern part of the Pieniny Klippen Belt.

Palaeontology

This chapter is not assigned for the systematic description of the whole fauna. Only some Early Jurassic to early Middle Jurassic taxa, which are new or poorly known in the West Carpathian area or they are of greater palaeobiogeographical significance, will be described in detail. Representants of the suborders Phylloceratina and Lytoceratina are shortly discussed in the next paragraph. The palaeontological material described and figured in the paper is stored in the collection of the Department of Geology and Paleontology, Faculty of Sciences, Comenius University in Bratislava (coll. Schlögl).

Phylloceratina from the Aalenian marly crinoidal limestones and marlstones composes in majority of phosphatised smooth internal casts of *Phylloceras perplanum* Prinz (37 specimens, Fig. 7.2), meanwhile constricted genus *Holcophylloceras* is rare, present by a few specimens of *Holcophylloceras* sp. juv. [cf. *H. ultramontanum* (Zittel)] (Fig. 7.3). Other three deformed and fragmented internal casts of *Ptychophylloceras* (*Tatrophylloceras*) cf. *tatricum* (Pusch) have been collected from the overlying grey crinoidal limestones. They are associated with typical fauna of the Middle – Late Aalenian, *L. murchisonae* – *G. concavum* Zones. Lytoceratina are rare. Only two taxa were collected in the Toarcian red marls and Aalenian grey marly crinoidal limestones. Among the resedimented phosphatised ammonites from *B. bradfordensis*/*G. concavum* Zone, two fragments of ?*Alocolytoceras* sp., with whorl section, shape of constrictions and the suture line close to *Alocolytoceras ophioneum* (Benecke) were found. Another specimen interpreted as *A. dorcadis* is described below.

Explanations of the abbreviations:

Terminology of the suture line: E – external lobe, S1 – 1st lateral saddle, S2 – 2nd lateral saddle, L1 – first lateral lobe, I – dorsal lobe

Measurements of the shell parameters: D – shell diameter, H – whorl heigth, E – whorl width, O – umbilicus diameter

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Lytoceratidae Neumayr, 1875
Alocolytoceratinae Spath, 1927
Alocolytoceras Hyatt, 1900

Alocolytoceras dorcadis (Meneghini, 1881)
Fig. 7.1 a-c

1967 *Alocolytoceras dorcadis* (Meneghini) – Géczy, p. 79, Pl. 22, Fig.1, Pl. 64, Fig. 32, Text-fig. 82 (cum syn.)
2001 *Audaxlytoceras dorcadis* (Meneghini) - Venturi & Ferri, p. 91, 248, non p. 92 a,b

Material: Fragment of a whorl.
Dimensions: Because of only a small part of the ammonite preserved its diameter is not directly measurable. The reconstruction indicates it attains between 350 and 400 mm. H (whorl height) of the fragment is 66 mm and E (whorl width) is 49,5 mm.
Remarks: The taxon *Alocolytoceras dorcadis* is characterized by compressed elliptical whorl section during whole ontogeny. The maximum width is in the middle of the flanks. Another typical character is the high number (6) of the prorsiradiate constrictions, well prononced around the whorl.
Suture line (Fig. 7.1) is typical lytoceratid with shallow E (only ½ of the height of the L1). S1 and S2 are highly differentiated with narrow trunks and deeply cutted folioles. I is cruciform.
As it is clear from the literature the biggest specimens of this taxon do not exceeded 100 mm.
Distribution: Red marls of the Hŕbok Marl Fm., locality Beňatina. It is associated with *Frechiella subcarinata* (Young & Bird), proving its Middle Toarcian age, *H. bifrons* Zone.

Arietitidae Hyatt, 1875
Arietitinae Hyatt, 1875
Coroniceras Hyatt, 1875

Coroniceras lyra Hyatt, 1867
Fig. 7.4 a,b, 8.3 a,b

1966 *Coroniceras lyra* Hyatt - Guerin-Franiatte, p. 134, Text-fig. 35-39, Pl. 22-25, Pl. 26, Fig. 1-3 (cum syn.)
1987 *Coroniceras lyra* Hyatt – Corna, p. 100, Pl. 1, Fig. 5

Material: 3 fragments of big specimens (the biggest attained almost 400 mm).
Remarks: All specimens agree well with the Guerin-Franiatte description of the species (1966: 134). Subadults (diameter cca 100 mm) have a subquadrate whorl section, with H slightly smaller than E. Ventrum is tricarinate and bisulcate (Fig. 7.4b, 8.3b). Lateral keels are pronounced, but smaller than the middle one. The grooves are deep. The ribs are strong, prorsiradiate with short ventro-lateral projection, joining the lateral keel. There are no ventrolateral tubercles on the ribs. The distance between the ribs is two times their thickness. Adult whorl section is round-oval, slightly compressed. Ventral part is bisulcate, ventral keel is very strong. Lateral keels become indistinct. Ribs are robust, prorsiradiate and distant.
Suture line is only partially preserved. E is narrow and deep. S1 is robust, narrowed in the upper part and smaller than S2. L is shalow and attains only ½ of the height of the E.
Distribution: The taxon is well distributed in the continental Europe, but rare in the Western Carpathians. It was found in only two localities: Beňatina and Butkov (lgt. Dr. J. Michalík). Early Sinemurian, *A. semicostatum* Zone.

Coroniceras (Paracoroniceras) Spath, 1924
Coroniceras (Paracoroniceras) cf. *charlesi* Donovan, 1955
Fig. 8.2

Material: Fragment of internal cast of an adult whorl.
Remarks: At the base of its characteristic whorl section the specimen can be very probably assigned to species *C. (P.) charlesi*. Adult whorl section is subtriangular with relatively narrow, tricarinate and bisulcate ventrum. The maximum width is in the periumbilical third of the whorl. *Coroniceras (Paracoroniceras) crossi* (Wright) (sensu Corna 1987, Pl. 1, Fig.7) is very close to our specimen in the similar whorl section but the grooves in this taxon are less pronounced. Moreover the species *C. (P.) crossi* is frequently considered as synonym of the *C. (P.) charlesi* (cf. Guerin-Franiatte, 1966, p. 153).
Distribution: In the West Carpathians the taxon was found only in the Dolný Mlyn Fm. in the locality Beňatina. Early Sinemurian, *A. semicostatum* Zone.

Hildoceratidae Hyatt, 1867
Bouleiceratinae Arkell, 1950
Frechiella Prinz, 1904

Frechiella subcarinata (Young & Bird, 1822)
Fig. 9.8 a-d

2003 *Frechiella subcarinata* (Young & Bird) – Rulleau et al., p. 332, Figs. 13 (2, 3, 5), 14 (1) (cum syn.)

Material: One incomplete internal cast.

Dimensions:	D	H	E	O
	53,6	25,0	24,8	10,0 (phragmocon)

Remarks: It is typical by robust and involute shell with oval whorl section (Fig. 9.8c). Umbilicus is narrow and deep with rounded umbilical wall, gradually passing to slightly arched flanks. Ventrum is bisulcate and tricarinate. Lateral keels are higher but less pronounced than median keel. Juvenile whorls bear radiate, regularly arranged ribs on the flanks which are strong mainly near the periumbilical area. The ribs become less pronounced and more irregularly arranged in the course of ontogeny.

The suture lines are crowded at the end of the preserved phragmocon. E and relatively narrow L1 are similarly deep. S1 is large, divided in two by central shallow accessory lobe. S2 is almost as hight as S1 but narrower. Auxiliary saddles are low, less divided and apparently smaller than S2.

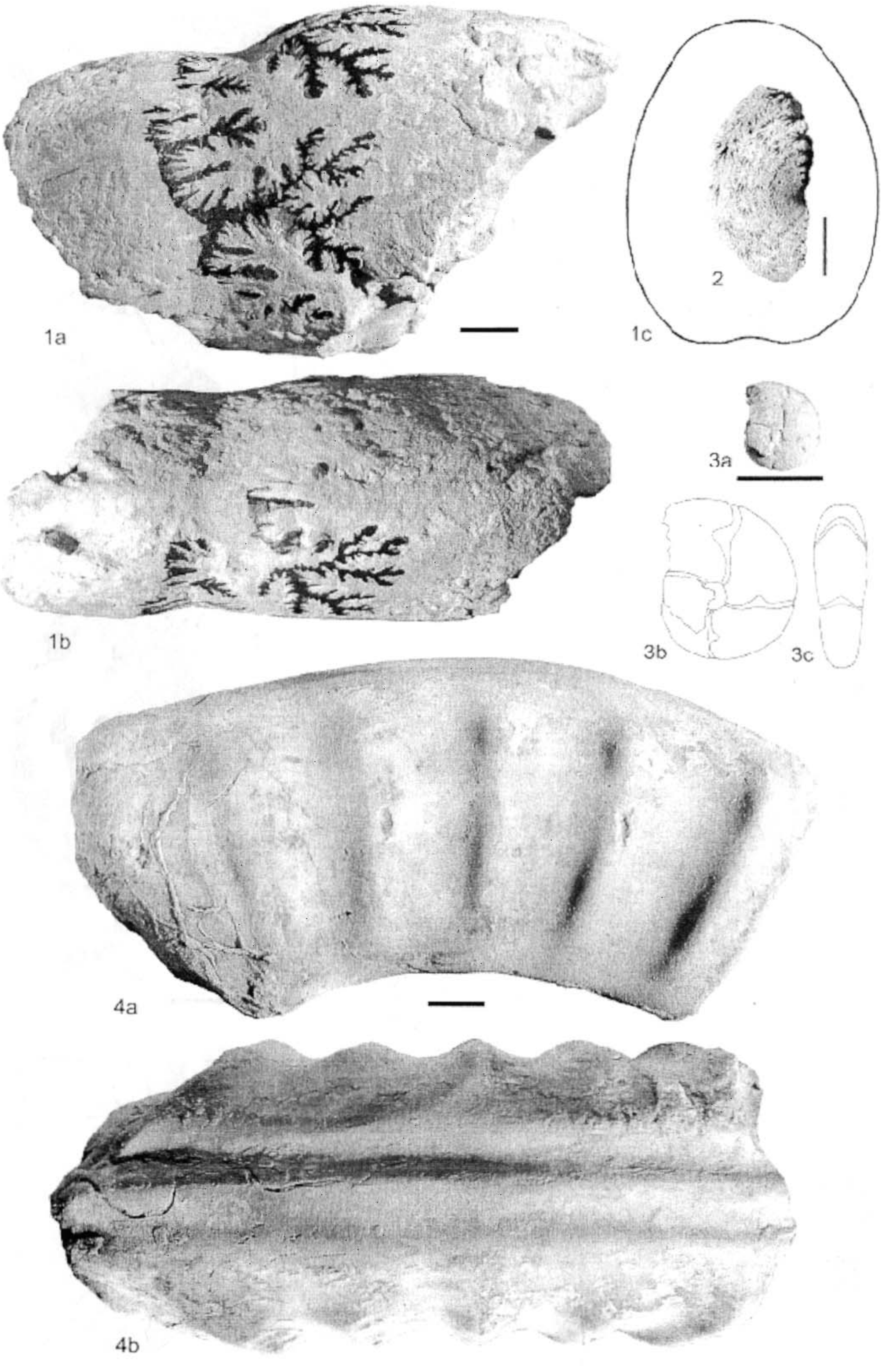

Fig. 7. 1a-c. *Alocolytoceras dorcadis* (Meneghini), Middle Toarcian, Hŕbok Marl Fm. 2. *Phylloceras perplanum* Prinz, Aalenian, Member A. 3. *Holcophylloceras* sp. juv. [cf. *H. ultramontanum* (Zittel)]. 4a, b. *Coroniceras lyra* Hyatt, Early Sinemurian, Dolný Mlyn Fm. (Scale bar = 1 cm)

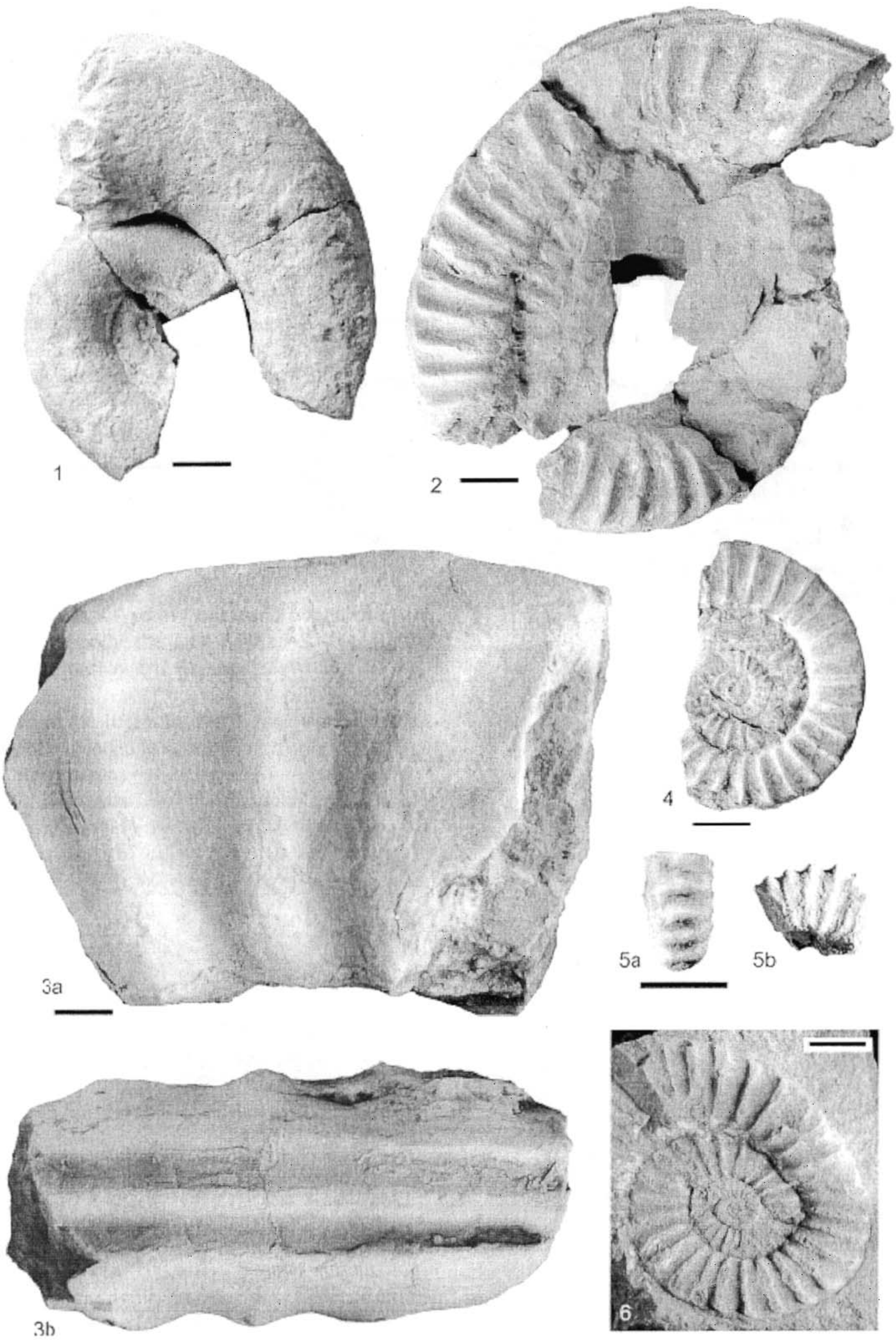

Fig. 8. *Lytoceras* cf. *sublineatum* (Oppel), Late Toarcian, Hŕbok Marl Fm. 2. *Coroniceras (Paracoroniceras)* cf. *charlesi* Donovan, Early Sinemurian, Dolný Mlyn Fm. 3a, b. *Coroniceras lyra* Hyatt, Early Sinemurian, Dolný Mlyn Fm. 4. *Arnioceras semicostatum* (Young & Bird), Early Sinemurian, Dolný Mlyn Fm. (ex situ). 5a, b. *Bifericeras* sp., Late Sinemurian, Allgaü Fm. (ex situ). 6. *Arnioceras* sp., Early Sinemurian, Dolný Mlyn Fm. (ex situ). (Scale bar = 1 cm)

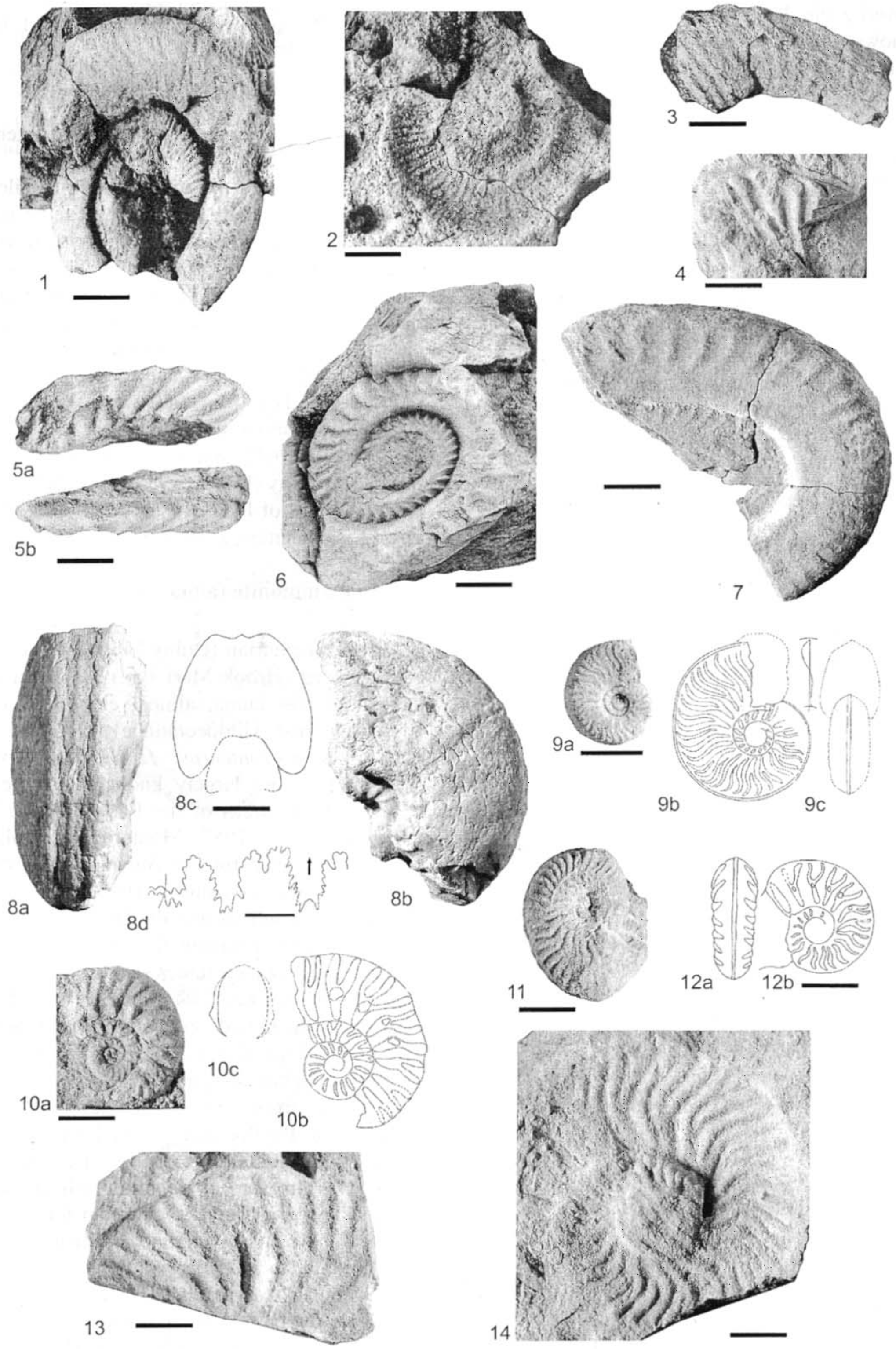

Fig. 9. 1. *Dactylioceras* cf. *tenuicostatum* (Young & Bird), Early Toarcian, Hŕbok Marl Fm. 2. *Dactylioceras* sp., Late Domerian, Hôrka Fm. 3. *Dactylioceras* sp., Early Toarcian, Hŕbok Marl Fm. 4. *Pleuroceras* cf. *solare* (Phillips), Late Domerian, Allgäu Fm. 5a, b. *Pleuroceras* cf. *spinatum* (Bruguière), Late Domerian, Allgäu Fm. 6, 7. *Hildoceras lusitanicum* Meister, Middle Toarcian, Hŕbok Marl Fm. 8a-d. *Frechiella subcarinata* (Yound & Bird), Middle Toarcian, Hŕbok Marl Fm. 9a-c. *Brasilia (B.)* sp. juv. [cf. *Brasilia (B.) bradfordensis* (Buckman)], reworked phosphatised cast, Aalenian, crinoidal limestones, Member A. 10a-c, 12a, b. *Ludwigia* sp., reworked phosphatised casts, Aalenian, Member A. 11. *Brasilia (B.)* gr. *bradfordensis* (Buckman), Aalenian, crinoidal limestones, Member A. 13. *Graphoceras* sp., Aalenian, crinoidal limestones, Member A. 14. *Ludwigia* (*Pseudographoceras*) sp., Aalenian, crinoidal limestones, Member A. (Scale bar = 1 cm)

Distribution: The taxon is restricted to the Middle Toarcian, *H. bifrons* Zone. It is very rare in the Western Carpathians, known from two localities only, Beňatina and Červený Kameň – Podbiel (Rakús, 1994).

Graphoceratidae Buckman, 1905
Graphoceratinae Buckman, 1905
Ludwigia Bayle, 1878

Ludwigia sp.
Fig. 9.10 a-c, 9.12 a,b

Material: Four incomplete subadult specimens.
Remarks: All material is represented by juvenile and subadult specimens. They are evolutely coiled with suboval whorl section. Ventrum is arched, bearing a blunt keel. Subadult whorl section becomes high-oval with arched ventrum, without distinct keel. Flanks are only slightly convex, almost parallel in the middle of the flanks (Fig. 9.10c).
The first two whorls are smooth, the first simple but strong ribs appear on the third whorl. On the fourth whorl they become bifurcate, always alternating with the simple ones. On the fifth whorl the ribs are irregularly divided: first trifurcate ribs appear. They bear small tubercles at the point of division. The ribbing fade out on the ventrolateral margin.
Suture is visible on the juvenile whorls only, E and L are of the same depth. Also the lateral saddles are of the same heigh.
Distribution: The material comes from grey marly crinoidal limestones. The specimens are associated with *Brasilia (B.)* sp. juv. [cf. *B. (B.) bradfordensis*], indicating Aalenian, *L. murchisonae* Zone.

Ludwigia (Pseudographoceras) sp.
Fig. 9.14

Material: One incomplete negative imprint.
Remarks: The specimen comes from the light-grey slightly sandy limestones. The shell is weakly involute (D = 55 mm) with narrow and arched ventral side. The ribs are sigmoidal, bifurcate and their radial line is versiradiate (sensu Gabilly, 1976, p. 59). The type of ribbing indicates its belonging to the subgenus *Pseudographoceras*.
Distribution: Grey slightly sandy crinoidal limestones, *L. murchisonae* Zone.

Graphoceras Buckman, 1898
Graphoceras sp.
Fig. 9.13

Material: Two incomplete imprints of the outer whorls.
Remarks: Involutely coiled ammonite with narrow umbilicus, flat and high whorls with rursiradiate strong and bifurcate ribs. Ventral side is narrow and arched. Radial line is anguliradiate – cranked in the form of a largely open V. These characters are typical of *Graphoceras*.
Distribution: Light-grey fine-grained crinoidal limestones, Aalenian, probably *G. concavum* Zone.

Brasilia Buckman, 1898

Brasilia (B.) sp. juv. [cf. *Brasilia (B.) bradfordensis* (Buckman, 1887)]
Fig. 9.9 a-c

Material: One incomplete phosphatised internal cast of a juvenile ammonite.
Remarks: Although the specimen is juvenile, at the base of the type and density of ribbing it can be assigned to the species *B. (B.) bradfordensis*. It is involute with relatively narrow umbilicus (Fig. 9.9 a,b). The whorl section is compressed with arched ventral side and flat convergent flanks. Umbilical wall is rounded. The whorls bear dense, bifurcate, slightly sigmoidal ribs. Radiale line is versiradiate with long proximal segment.
Distribution: Taxon is rare in the Western Carpathians, untill now known only from the locality Litmanová (Scheibner, 1964) and from the locality Lukoveček, Hostýnske vrchy (Rakús, 1987). It is also known from the Ukrainian part of Pieniny Klippen Belt (Kalinitchenko et al., 1965). Aalenian, *L. murchisonae* Zone.

Notes on ammonite fauna

Early Sinemurian (Dolný Mlyn Fm.) as well as Toarcian deposits (Hŕbok Marl Fm.) yielded a quite ubiquitous ammonite fauna, almost essentially composed of Arietitidae and Hildoceratidae (Fig. 12). The genera *Arnioceras, Coroniceras, Hildoceras, Frechiella* and *Dactylioceras* are largely known from the epiplatform and epioceanic areas of the Early Jurassic Tethys (Dommergues et al., 1987, Mouterde & Elmi, 1991). The same can be state for the Aalenian deposits, where the Graphoceratidae constitutes 100% of the Ammonitina. On the other hand, during the Domerian and very probably also during Carixian the area of study (Czorsztyn Ridge) clearly stayed under strong Sub-boreal influence. The Sub-boreal taxa *Pleuroceras* and *Amaltheus* are common in the Domerian deposits of the Pieniny Klippen Belt successions (Rakús, 1990b, Schlögl et al., 2000). Another Sub-boreal genus *Liparoceras* was also frequently cited from the Carixian (e.g. Schlögl, 1998).
Presence of Phylloceratina and Lytoceratina was controled by local ecological factors. They are generally associated with deeper, pelagic Tethyan environments. Their scarcity or absence in certain formations points to unfavourable palaeoecological situation. Lytoceratina were completely absent in the Early Sinemurian and Late Domerian and very rare in the *L. murchisonae* and *G. concavum* Chrons of the Aalenian (Fig. 12). Phylloceratina were totally absent during the Early Sinemurian. In the Late Domerian, Toarcian and Aalenian they constitute between 15% and 25% of the whole fauna. Their anomalous high percentage among reworked phosphatised fauna of the Middle Aalenian (more than 70%) could be caused by several primary or secondary processes, such as local oxygen-depleted conditions during the deposition of the dark marly layers. Sorting by bottom currents including size-sorting could also influenced the final ammonite spectrum. About 50% of both these necto-pelagic groups

in the Lower Bathonian ammonitico rosso deposits agrees with the assumed trend of Middle Jurassic deepening of the Czorsztyn Ridge (e. g. Wierzbowski et al., 1999).

During the Middle Jurassic the fauna had a typical Mediterranean character. Immigration of some South-Tethyan taxa took place during the *Z. zigzag* Zone of the Early Bathonian. Beňatina is the first Carpathian locality where the true Arabian ammonites were found (see Schlögl & Rakús, in press). Three specimens of *Micromphalites (M.)* aff. *pustuliferus* (Douvillé) have been collected. Early Bathonian *Micromphalites* are considered as imigrants from the Arabia - Sinaï area along the North-African and East-European continental margins (Enay et al., 2001, Schlögl & Rakús, in press). The Mediterranean

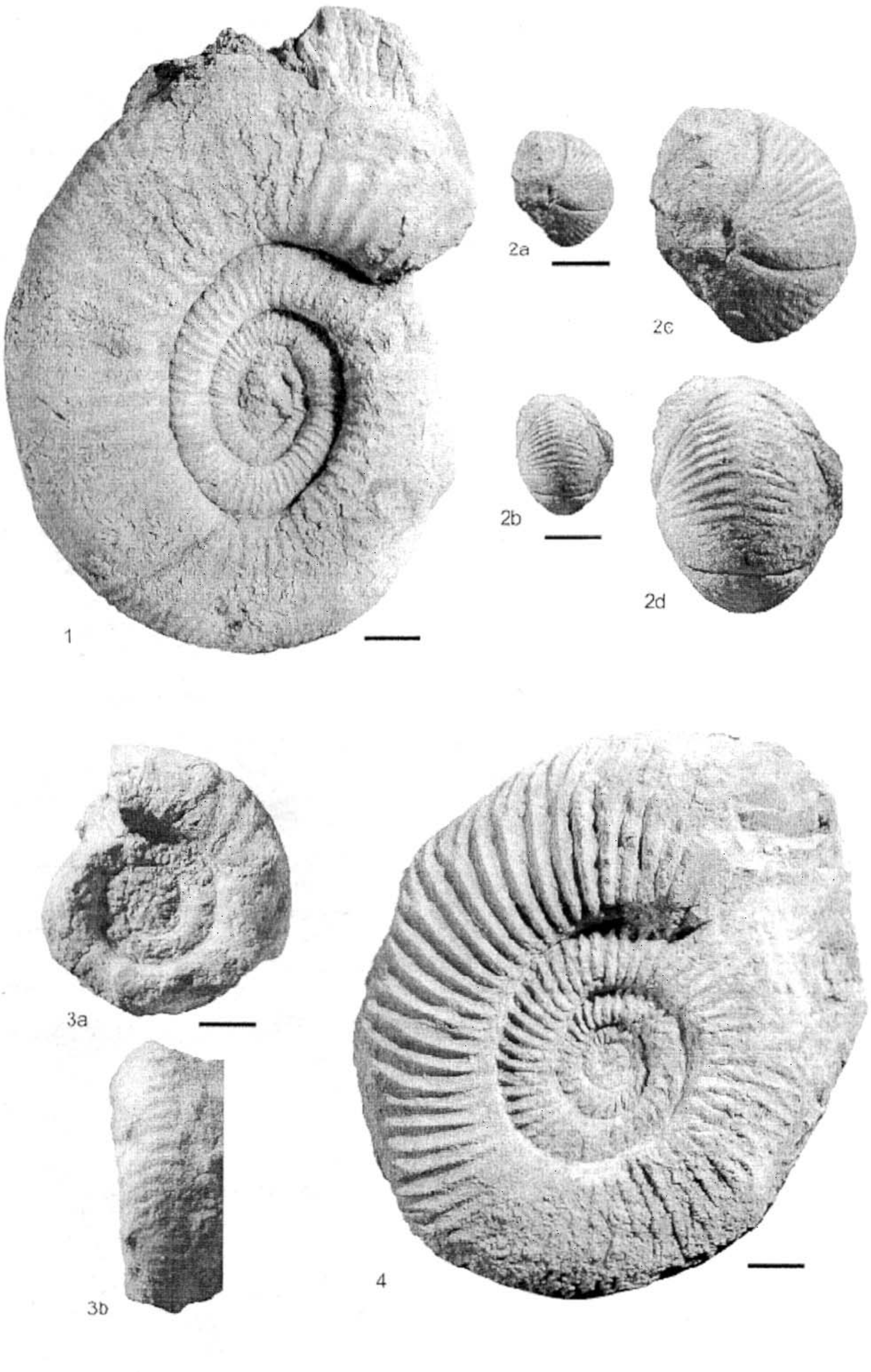

Fig. 10. 1. *Planisphinctes (Lobosphinctes) intersertus* Buckman, Early Bathonian, Czorsztyn Lst. Fm. 2a-d. *Morphoceras (M.)* cf. *dimorphitiformis* (Sandoval), Early Bathonian, Czorsztyn Lst. Fm. 3a-d. *Zigzagiceras (Z.) zigzag* (d'Orbigny), Early Bathonian, Czorsztyn Lst. Fm. 4. *Parkinsonia (P.) parkinsoni* (Sowerby), Late Bajocian, Czorsztyn Lst. Fm. (barscale 1 cm)

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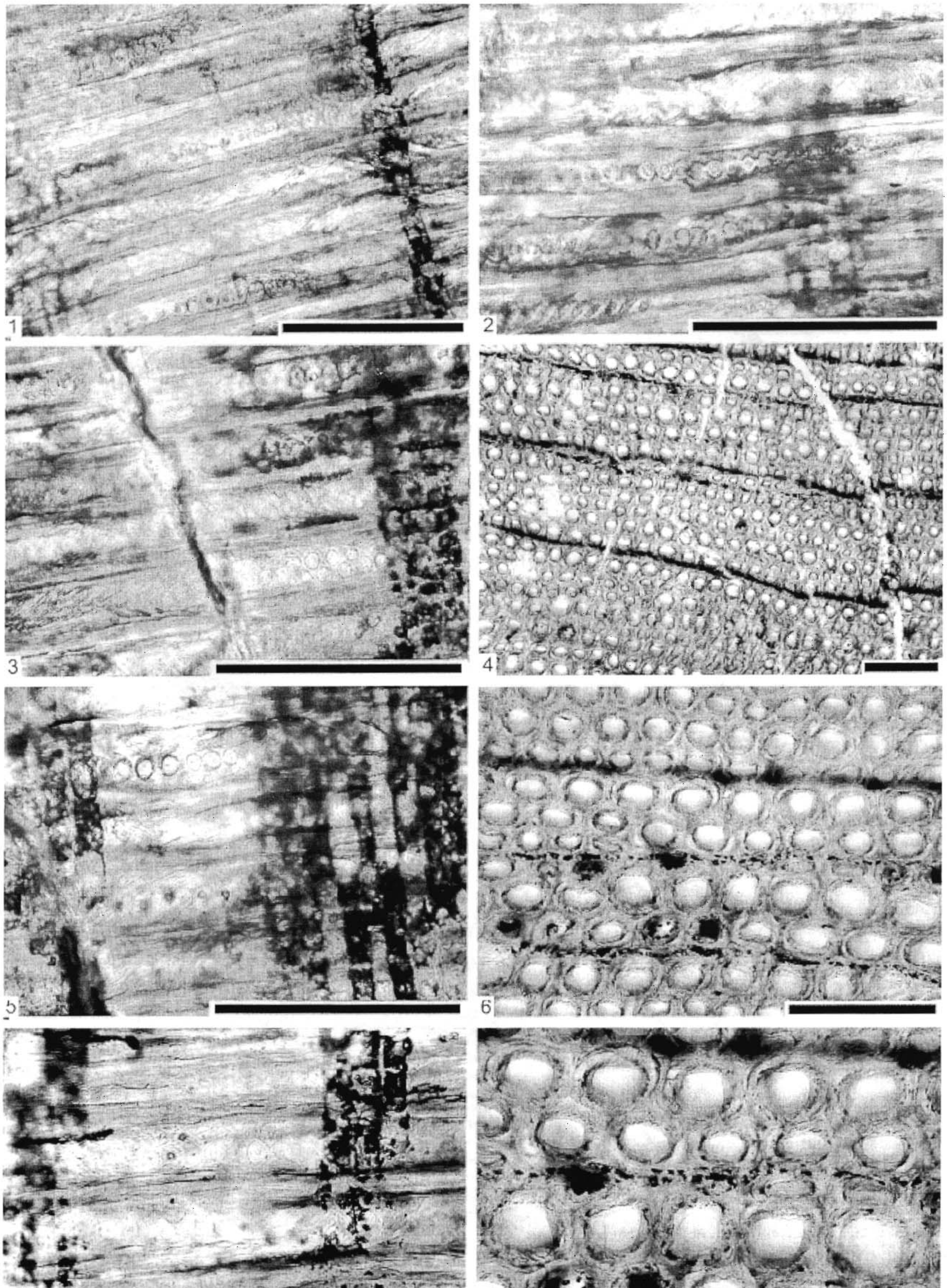

Fig. 11. *Brachyoxylon* sp., longitudinal (1 - 3, 5, 7) and transversal (2, 4, 6, 8) sections. Late Aptian, Nižná Unit. (Scale bar = 0,25 mm)

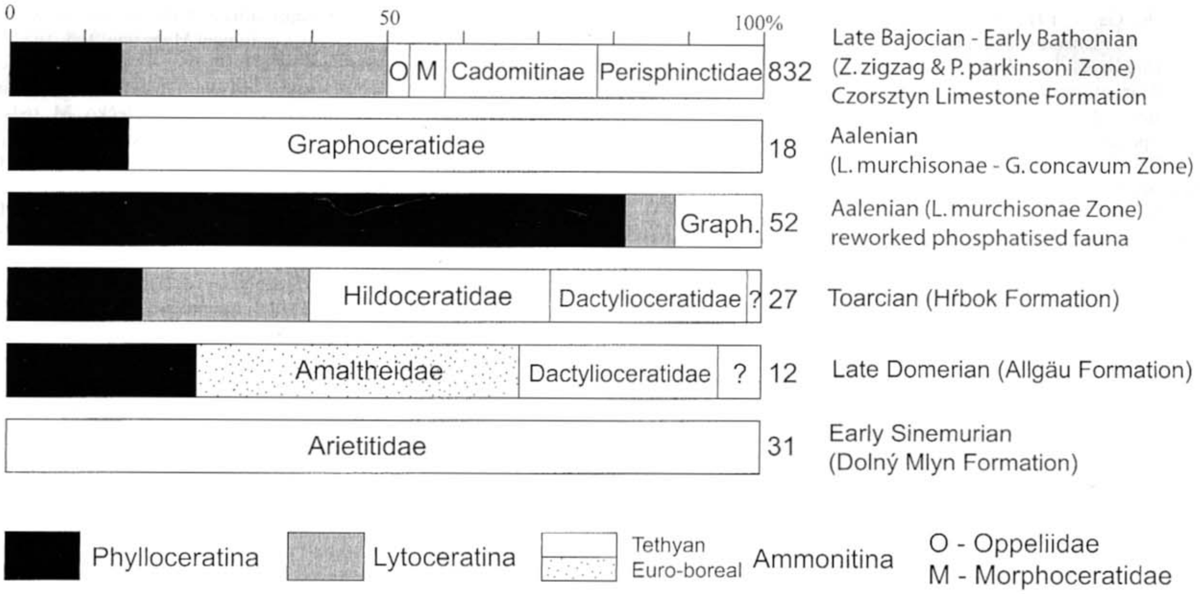

Fig. 12. Relative abundances of ammonite higher taxa from the most fossiliferous parts of the studied Beňatina sections. Dark and grey taxa represent necto-pelagic ammonites.

character of the Late Bajocian - Early Bathonian fauna (*P. parkinsoni* and *Z. zigzag* Chrons) is proved by high proportion of Phylloceratina and Lytoceratina (63%), which extensively prevail over Ammonitina (37%). Among Lytoceratina the genus *Nannolytoceras* is the most abundant (90 %), which is a common feature shared by the most localities studied in the Pieniny Klippen Belt area. The Ammonitina shows a very high percentage of Cadomitinae. This fact is caused by local abundance of very rare taxon *Benatinites* (*B.*) gr. *schlageri* (Krystyn) (Schlögl et al., in press). Presence of both Morphoceratidae and Parkinsoniinae allows the biostratigraphical correlations with the Mediterranean and NW-European areas.

Palaeobotany

Some layers within the Early Cretaceous part of the section contain incrusted wood fragments with well preserved internal structure. On the base of their anatomy they clearly belong to conifers (Pinopsida), most probably to the genus *Brachyoxylon*. Perpendicular and transversale sections show typical araucarian and abietineous type of pitting (Fig. 11). Very similar forms have been described by Laudoueneix (1973) from the Tchad (Central Africa). Another occurences (under the name *Brachyoxylon brachyphylloides* (Torrey) were reported from USA (Torrey, 1923) and from Tunisia (Boureau, 1952). Stratigraphic range of the species is from Middle Jurassic to Middle Cretaceous.

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