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# STRATIGRAPHY OF CRETACEOUS SEDIMENTS OF THE MAGURA GROUP OF NAPPES IN MORAVIA (CZECH REPUBLIC)

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**Abstract:** In the Magura Group of nappes, Cretaceous sediments were proved in the Rača and Bílé Karpaty units nearly in the whole range of the period. This was made possible by new biostratigraphic (foraminifers and calcareous nannofossils) and biofacies data. In the present paper, the Kurovice Klippe, Gault Flysch, Kaumberg Formation and the lower part of the Soláň Formation are included in the Rača Unit, while the Hluk, Kaumberg and Javorina formations and the lowermost part of the Svodnice Formation are placed in the Bílé Karpaty Unit. Some lithostratigraphic units of Senonian age appear in tectonic slices only (Púchov Marl and Antonínek Formation) which makes their incorporation into the paleogeographical model of the Magura Group of nappes difficult.

**Key words:** Western Carpathians, Outer Flysch Belt, Magura Group of nappes, Cretaceous, lithostratigraphy, biostratigraphy.

## Introduction

The Magura Group of nappes is the significant regional unit of the Outer Western Carpathians (Fig. 1) in which sediments from the Upper Jurassic up to the Miocene were proved.

Until the 1980s, the presence of the Cretaceous was not respected at all in the Magura Group of nappes in the territory of Moravia. The prevailing flysch deposits were considered solely Paleogene (Matějka & Roth 1956; Pesl 1965, 1968).

In contrast, Cretaceous deposits were reported in the Polish part of the Magura Group of nappes by Sikora & Zytko (1959), Geroch et al. (1967), Oszczypko (1992) and others. Biely et al. (1996) marked the Cretaceous flysch sediments in the Magura Group of nappes on the Geological Map of Slovakia. Cretaceous sediments were also known in the Rhenodanubian Flysch of Austria (Götzinger 1954; Prey 1980) and Western Bavaria (Hesse 1973) which is the continuation of the Magura Group of nappes.

In the Moravian part of the Magura Group of nappes the Cretaceous sediments were in the past described only in isolated tectonic slices in the front of the Rača Unit (Fig. 2) in the Kurovice area (Matějka in Buday et al. 1967; Benešová et al. 1968) and in the front of the Bílé Karpaty Unit near the villages of Hluk and Blatnice (Plička 1957; Stráník et al. 1995). Compared with the main mass of nappes they represent different litho- and biofacies developments within the Cretaceous (Bubík 1995).

On the basis of new litho- and biostratigraphic study made on foraminifers and calcareous nannofossils, Cretaceous sediments were found in the Rača and Bílé Karpaty units nearly in the whole range. In the Bystrica Unit, sediments of the Cretaceous age have not been observed in the territory of the Czech Republic.

The Lower Cretaceous was newly described in the Rača Unit in the Hostýnské vrchy Hills (Bubík et al. 1993), the Upper Cretaceous in a number of places in the Rača Unit (e.g. Pesl & Švábenická 1988) and in the Bílé Karpaty Unit (Švábenická 1990, 1992; Švábenická & Bubík 1992; Vujta et al. 1989; Potfaj 1993; Bubík 1995; Stráník et al. 1995).

## Geological development of the Magura depositional area

The depositional area of the flysch units of the Magura Group of nappes was formed by the creation of basinal, trough zones formed in the process of the Jurassic rifting of the European-African platform.

In the Triassic the northern Tethyan margin was under conditions of a slowly sinking shelf with a very limited fault activity. During the Lias and Dogger numerous normal faults were actived and elevation and depression zones originated. This fault activity caused the opening of the Central Atlantic Ocean, when a long-term extension trend between Eurasia and Africa began and when the new paleogeographical domains of the Eastern Alps and the Western Carpathians originated (Tricart 1984). These domains were locally divided into a number of subdomains belonging to individual nappe systems known till now.

In accordance with Tricart (1984) the Flysch Belt of the Western Carpathians can be classified into particular domains. The Outer Group of nappes (Menilite-Krosno Group) can be put to the Helvetic domain. The Magura depositional area probably belonged to the North Penninic (the Valais) domain. Soták (1992) joined the Magura depositional area to the Pieniny-Magura basin on the basis of the Mesozoic pebble material that was found in the Soláň Formation of the Rača Unit (Hostýn and Tři kameny lithofacies zones) in the Chřiby Highland and Hostýnské vrchy Mts. Further in the internal part of the Bílé Karpaty Unit there are obviously some

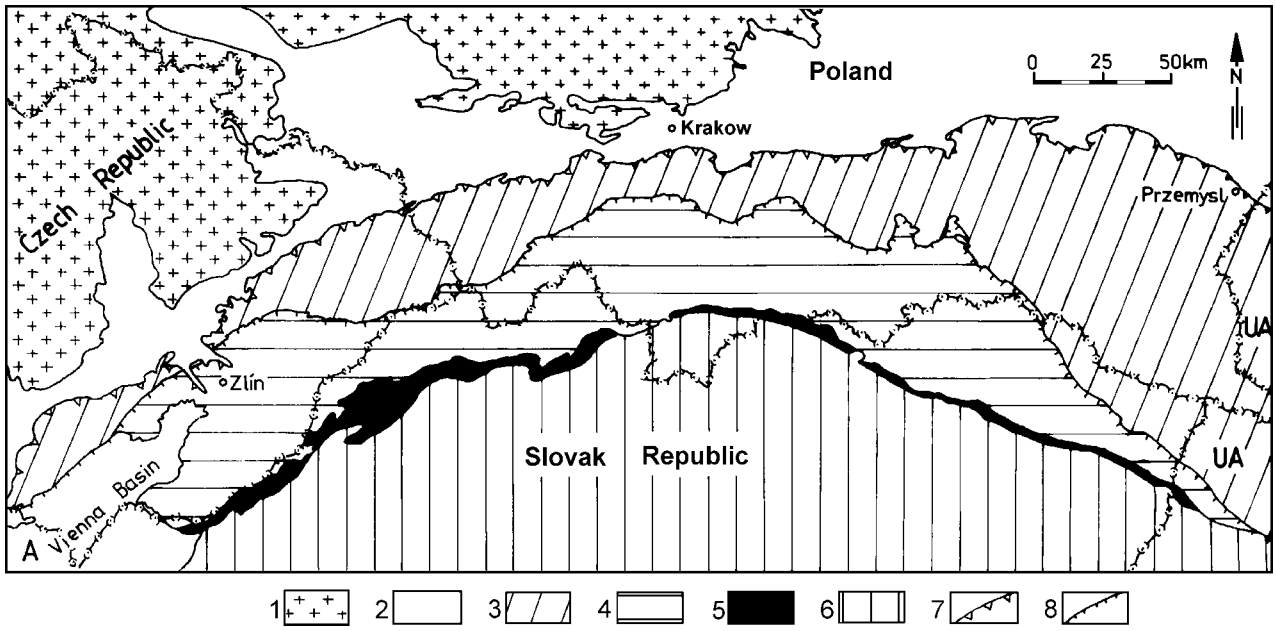



**Fig. 1.** Tectonic map of the West-Carpathian area with the spread of the flysch units. **1** — Bohemian Massif with the pre-Tertiary cover sediments; **2** — Neogene sediments of the Carpathian Foredeep; **3** — Outer Group of nappes; **4** — Magura Group of nappes; **5** — Pieniny Klippen Belt; **6** — Central Carpathians; **7** — frontal flysch nappes overthrust; **8** — partial thrust faults. **A** — Austria, **UA** — Ukraine.

common features with flysch of the Pieniny Klippen Belt and its detached zone in the Paleogene. Above all, it is an abundance of the carbonate detritus derived from the nappes of the Pieniny Klippen Belt and the occurrence of the "couches-rouges" sediments — Púchov Marl of the Campanian and Maastrichtian age in the Hluk area.

The western part of the Magura Group of nappes is divided into the Rača, Bystrica and Bílé Karpaty units (Fig. 2). The facies developments of the first two mentioned units are very similar. The sediments of the Bílé Karpaty Unit are quite different, especially in the Paleogene.

The neo-Alpine movements in the Eocene and Oligocene gradually ended the sedimentation in the Magura depositional area. Nevertheless, Cieszkowski (1992) suggested continuous sedimentation up to the Middle Miocene in the Podhale region (South Poland). The final nappe structure and the present position of the nappes in the Flysch Carpathian Belt resulted from the Styrian orogeny during the Lower and Middle Miocene.

The primary depositional area of the Outer Group of nappes is supposed partially in the territory of the present Central Carpathians and it touched the southern rim of the North European Platform. Reconstructing the movements of the Magura Group of nappes it is necessary to take into consideration not only the thrust tectonics, but also the far-reaching horizontal SW–NE displacements (Ratschbacher 1991a,b).

## Methods

Biofacies study was based on foraminiferal thanatocoenoses obtained solely from hemipelagites. Five biofacies (sensu Bubík 1996) were determined in the Cretaceous sediments of the Magura Group of nappes:

1. Glomospira–Rhizammina biofacies (diagnostic features: purely agglutinated assemblage of low diversity with abundant *"Rhizammina"* sp. and representatives of the superfamily Ammodiscacea; environment: low-oxygen conditions below the CCD).

2. Marssonella biofacies (diagnostic features: mixed calcareous-agglutinated benthic assemblages with calcareous agglutinated taxa such as *Marssonella, Clavulinoides, Dorothia* etc., more or less planktonic foraminifers; environment: above the CCD, usually the continental slope sediments).

3. Rhabdammina–Rzehakina biofacies (diagnostic features: purely agglutinated assemblages consisting of abundant tubular astrorhizids like *Nothia, Bathysiphon, Rhabdammina* and various hormosinids, rzehakinides, lituolids, verneuilinids etc.; environment: usually deep-sea turbidite fans below the CCD).

4. Recurvoides–Paratrochamminoides biofacies (diagnostic features: purely agglutinated high-diversity assemblages with various *Paratrochamminoides* and *Recurvoides* representatives, hormosinids, verneuilinids and free of rzehakinids and tubular astrorhizids except *"Rhizammina"* sp.; environment: abyssal zone with significant detrital input, below the CCD).

5. Buzasina–Praecystammina biofacies (diagnostic features: purely agglutinated assemblages with abundant small smooth-walled *Buzasina, Haplophragmoides* and *Praecystammina* species; environment: abyssal zone with low detrital input, below the CCD).

The zonation sensu Geroch & Nowak (1984) and the later results by Neagu (1990) and Bubík (1995) was used for the biostratigraphic evaluation of agglutinated foraminifers.

Upper Cretaceous planktonic foraminifers were evaluated using the zones of Robaszynski et al. (1984) and the stratigraphic data of Caron (1985). Lower Cretaceous planktonic

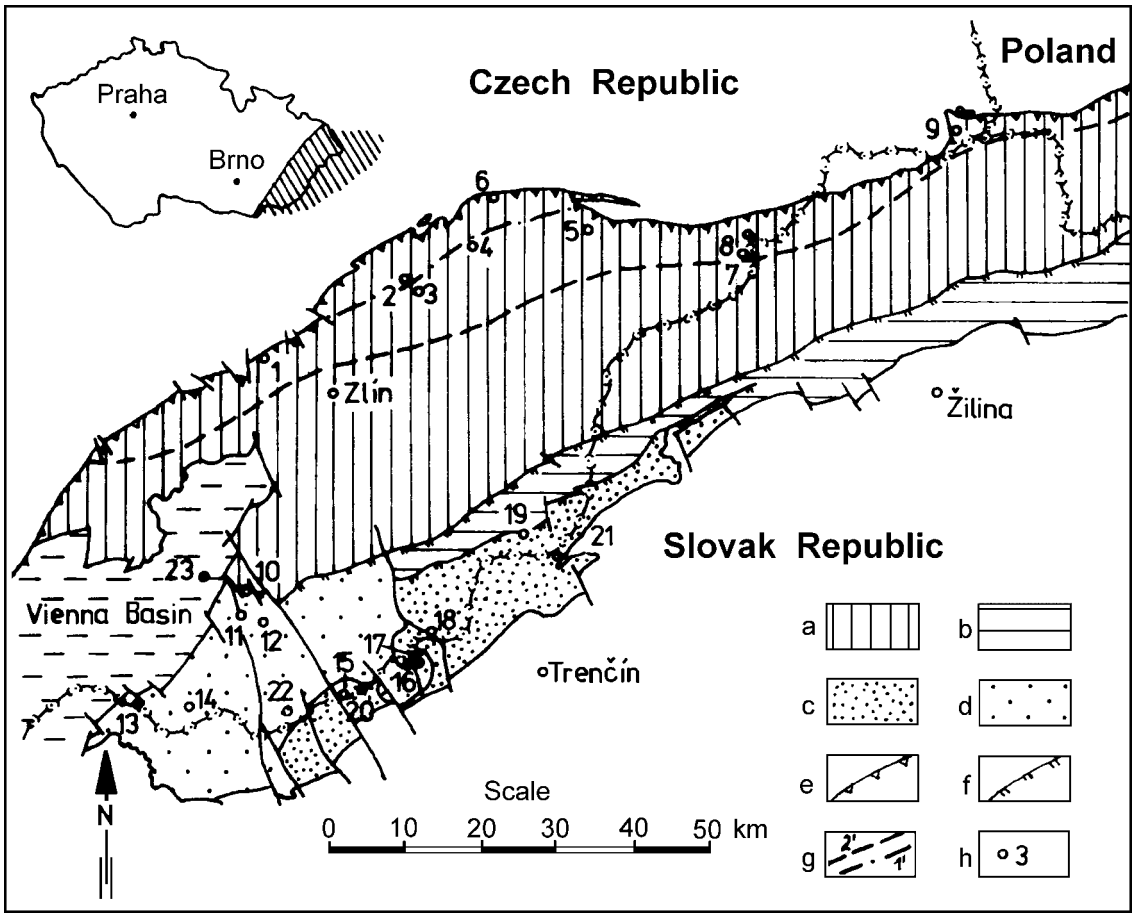



**Fig. 2.** Tectonic map of the western part of the Magura Group of nappes with localities where the Cretaceous sediments were found: **1** — Kurovice Klippe; **2** — Tesák; **3** — Rajnochovice; **4** — Mikuluvka; **5** — Valašská Bystřice; **6** — Valašské Meziříčí; **7** — Uzgruň; **8** — Salajka; **9** — Lísky; **10** — Hluk; **11** — Sv. Antonínek and Blatnice M-1 borehole; **12** — Kobylí hlava; **13** — Sudoměřice; **14** — Mandát; **15** — Javorina; **16** — Janegov mlyn; **17** — Velký Lopeník; **18** — Vyškovec; **19** — Štítná; **20** — Svinárský potok; **21** — Snoh; **22** — Filipovské údolí; **23** — Blatnice PVN-10 borehole. **a** — Rača Unit; **b** — Bystrica Unit; **c** — Vlára development of the Bílé Karpaty Unit; **d** — Hluk development of the Bílé Karpaty Unit; **e** — main Magura Nappe overthrust; **f** — partial thrust fault; **g** — southern borders of the Hostýn lithofacies zone and Tři kameny lithofacies zone; **h** — localities.

foraminifers were preliminarily determined and evaluated according to Banner & Desai (1988).

For the nannofossil study the samples were collected from turbidity calcareous claystones (interval $T_e$ sensu Bouma 1962). Biostratigraphic data were correlated mainly with the standard CC zones by Sissingh (1977) and Perch-Nielsen (1985). The Campanian sediments where only cosmopolitan and high-latitude nannofossils have been found were compared with the Boreal zonation suggested by Burnett (1990). In the Lower Paleocene, the standard NP zones by Martini (1971) were used. Data concerning province appurtenance of some nannofossil species were interpreted mainly according to Mutterlose (1992) and Wind (1979).

## Results

### *Rača Unit*

The Rača Unit is characterized by the prevailing sedimentation of black lithic flysch in the Lower Cretaceous and by variegated distal turbidity and hemipelagic sedimentation in the Senonian. In contrast the so-called Kurovice Klippe represents mainly carbonate sediments of the Late Jurassic to the Early Cretaceous age and sedimentary breccias of the Senonian age.

Flysch sediments of the Rača Unit were classified by Pesl & Krystek (1966) on the basis of their lithofacies development into several belt zones. The Cretaceous is present in the external Hostýn and Tři kameny lithofacies zones (Fig. 2). The lithostratigraphy of these zones was described by Pesl (1968).

*Kurovice Klippe*

**Kurovice Limestone**

The Kurovice Limestone was described by Glöcker (1841) and according to its aptychi assigned to the Jurassic. They are mostly grey micritic, medium- to thick-bedded limestones. The petrographic description was done by Eliáš in Benešová et al. (1968) and by Eliáš et al. (1996). The thickness of the limestones reaches up to 160 m.

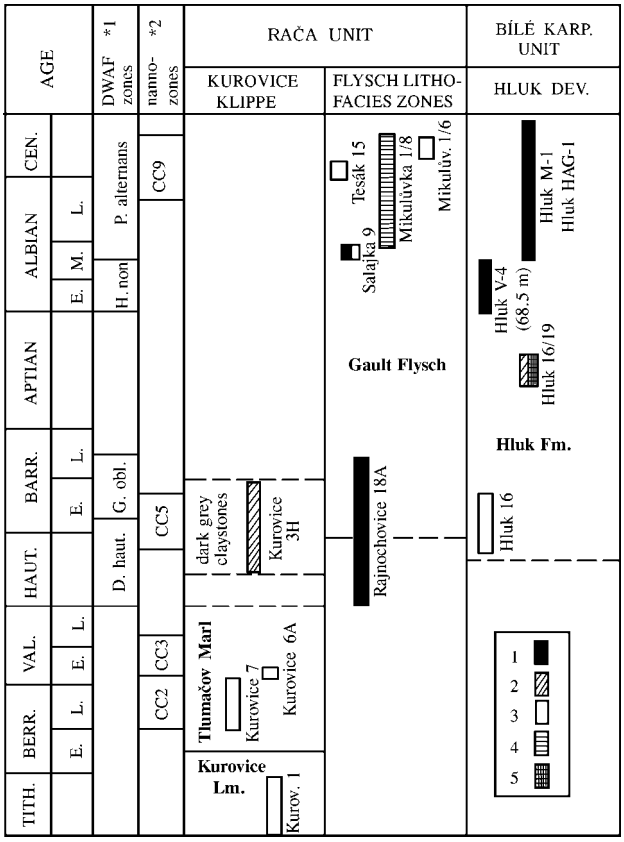



**Fig. 3.** Stratigraphic correlation chart of the Lower Cretaceous sediments of the Magura Group of nappes. The height of the columns shows the possible stratigraphic ranges of samples ascertained using the given microfossil group: 1 — agglutinated foraminifers; 2 — planktonic foraminifers; 3 — calcareous nannofossils; 4 — dinocysts; 5 — radiolarians. *1 — deep-water agglutinated foraminiferal zones sensu Geroch & Nowak (1984): **D. haut.** — *Dorothia* aff. *hauteriviana*; **G. obl.** — *Gaudryina oblonga*; **H. n.** — *Haplophragmoides nonioninoides*; **P. alternans** — *Plectorecurvoides alternans.* *2 — calcareous nannofossil zones sensu Sissingh (1977) and Perch-Nielsen (1985).

The age of the Kurovice Limestone was stated within the range ?Oxfordian–Kimmeridgian–Tithonian. Their upper limit was moved to the Early Berriasian by Vašíček & Reháková (1994), on the basis of aptychi and calpionellids.

In the Tithonian part of the Kurovice Limestone (Kurovice quarry, No. 1) nannofossils were found of species known from the Jurassic/Cretaceous boundary interval (Fig. 3), such as *Nannoconus globulus* and *Zeugrhabdotus erectus*. The dominant presence of genera *Cyclagelosphaera* and *Watznaueria* together with rare *Conusphaera mexicana* are typical features of the Tethyan bioprovince.

The foraminiferal fauna is badly preserved and poor, represented mostly by the specimens of genus *Lenticulina* (Benešová et al. 1968).

## Tlumačov Marl

The term Tlumačov Marl was introduced by Eliáš & Eliášová (in Andrusov & Samuel 1985) for sediments overlying the Kurovice Limestone. According to Vašíček & Reháková (1994) the intercalated beds of limestones in the lowermost exposed part of the Tlumačov Marl indicate its gradual transition from the Kurovice Limestone.

The Tlumačov Marl represents thin- to locally medium-bedded flysch with light grey marlstones to clay limestones (biomicrites). The thickness is assessed as up to 60 m (Eliáš & Eliášová l.c.). The carbonate turbidites may be correlated with the similar and stratigraphically equivalent sediments of the Silesian Unit (Těšín Limestone).

The age of the Tlumačov Marl was proved to be Berriasian–Valanginian by Vašíček & Reháková (1994), on the basis of aptychi and calpionellids.

Washed residues of the Tlumačov Marl are usually dominated by calcite casts of radiolarians. Foraminifers from the Tlumačov V-13 borehole (see Benešová et al. 1968) are represented by species *Caudammina crassa (=Rothina silesica), Pseudoreophax cisovnicensis* and *Protomarssonella(?) hauteriviana*, and they prove the Early Cretaceous age up to the Barremian.

The NK-2 Zone (sensu Bralower et al. 1989), hence the Early Berriasian age is documented by nannofossils *Retacapsa angustiforata* and *Rhagodiscus nebulosus* in the Kurovice quarry (No. 7, see Fig. 3). Nannofossils of the Valanginian age represented by rare *Micrantholithus speetonensis* (CC3b Zone) were found only in the clasts taken from the sedimentary breccia of the Kurovice quarry (No. 6A), which lithologically corresponds to the Tlumačov Marl.

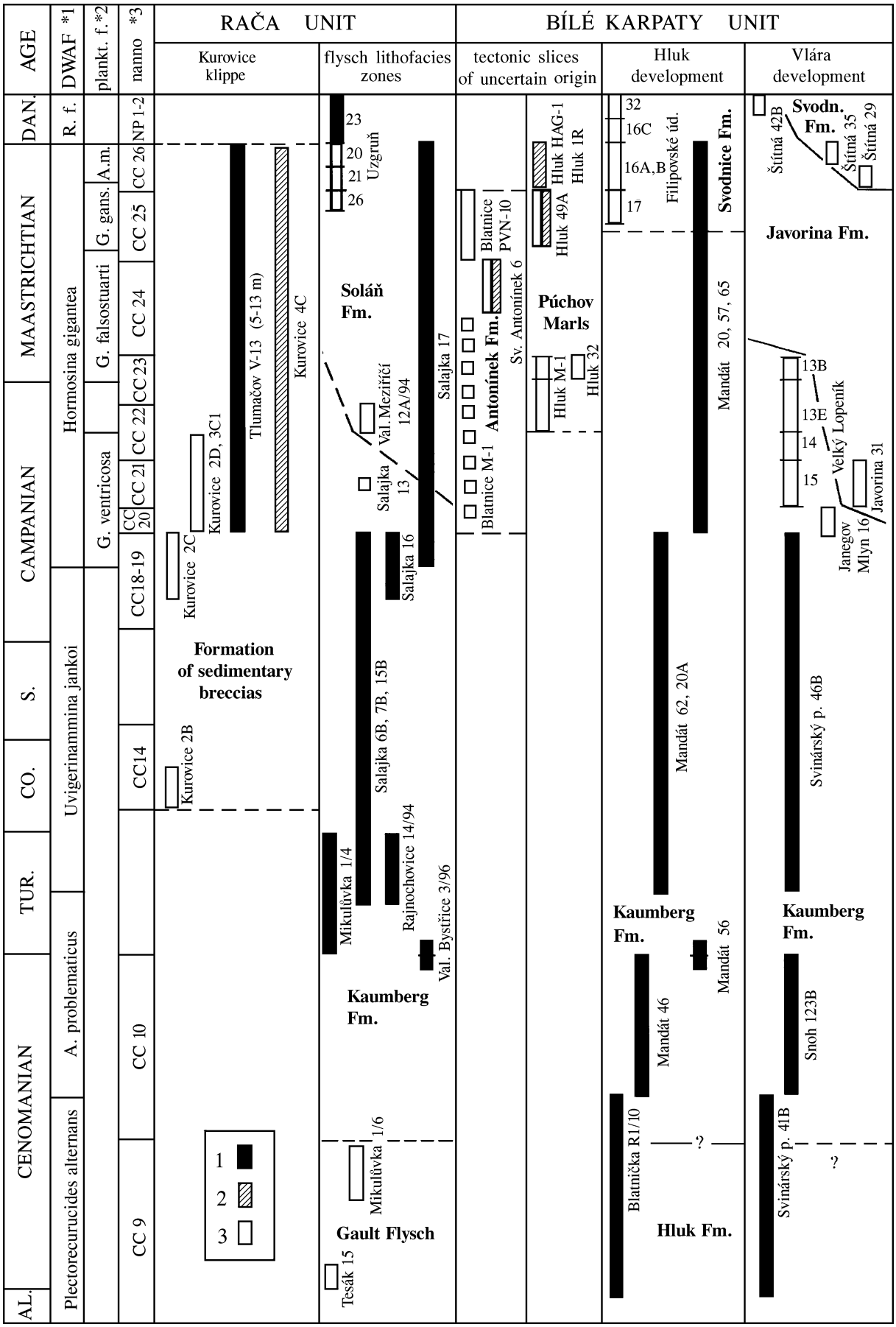
The flysch carbonate sedimentation, the absence of macrofauna with the exception of aptychi as well as the presence of the Marssonella biofacies indicate sedimentation in the outer turbidity fan at bathyal depths.

A rich microfauna with foraminiferal plankton, such as *Gorbachikella kugleri, G. anteroapertura* and *Praehedbergella handousi* (determined by BouDagher-Fadel, pers. comm.) was found in an isolated block of dark-grey claystone taken from a debris slope in the Kurovice quarry (No. 3H) and gave evidence for the Late Hauterivian age. According to the character of microfauna these sediments can be considered a part of the succession of the Kurovice Klippe, while their lithostratigraphic position remains uncertain.

## Formation of sedimentary breccias

Up to the present time the sedimentary breccias in the Kurovice Klippe were regarded as the Paleocene Soláň Formation of the Rača Unit transgressing over the Jurassic–Cretaceous carbonates (Benešová et al. 1968). The Formation of sedimentary breccias mostly consists of thick-bedded limestone breccias, in places with beds of variegated clays (for lithological description see Benešová et al. 1968 and Eliáš et al. 1996). The clastic material was derived mostly from the

**Fig. 4.** Stratigraphic correlation chart of the Upper Cretaceous sediments of the Magura Group of nappes. 1 — deep-water agglutinated foraminiferal zones sensu Geroch & Nowak (1984): **A. problematicus** — *Ammobaculites problematicus*; **R. f.** — *Rzehakina fissistomata*. 2 — planktonic foraminiferal zones sensu Robaszynski et al. (1984): **G. gans.** — *Gansserina gansseri*; **A. m.** — *Abathomphalus mayaroensis*. 3 — calcareous nannofossil zones sensu Sissingh (1977) and Perch-Nielsen (1985). For other explanation see Fig. 3.


AGE
DWAF *1
plankt. f. *2
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RAČA UNIT
BÍLÉ KARPATY UNIT
Kurovice klippe
flysch lithofacies zones
tectonic slices of uncertain origin
Hluk development
Vlára development
DAN.
R. f.
NP 1-2
MAASTRICHTIAN
CAMPANIAN
CENOMANIAN
G. gans.
A.m.
CC 26
CC 25
G. falsostuarti
CC 24
CC23
G. ventricosa
CC 22
CC 21
CC 20
CC18-19
CC14
CC 10
CC 9
S.
CO.
TUR.
Hormosina gigantea
Uvigerinammina jankoi
A. problematicus
Plectorecurucides alternans
AL.
Kurovice 2C
Kurovice 2D, 3C1
Tlumačov V-13 (5-13 m)
Kurovice 4C
Kurovice 2B
Formation of sedimentary breccias
Mikulůvka 1/4
Salajka 6B, 7B, 15B
Rajnochovice 14/94
Val. Bystřice 3/96
Kaumberg Fm.
Mikulůvka 1/6
Gault Flysch
Tesák 15
23
20
21
26
Uzgruň
Soláň Fm.
Salajka 13
Val.Meziříčí 12A/94
Salajka 16
Salajka 17
Blatnice M-1
Antonínek Fm.
Blatnice PVN-10
Sv. Antonínek 6
Hluk HAG-1
Hluk 1R
Hluk 49A
Púchov Marls
Hluk M-1
Hluk 32
32
16C
16A,B
17
Filipovské úd.
Svodnice Fm.
Mandát 20, 57, 65
Mandát 62, 20A
Kaumberg Fm.
Mandát 56
Mandát 46
Blatnička R1/10
Hluk Fm.
?
Štítná 42B
Svodn. Fm.
Štítná 35
Štítná 29
Javorina Fm.
13B
13E
14
15
Velký Lopeník
Janegov Mlyn 16
Javorina 31
Svinárský p. 46B
Kaumberg Fm.
Snoh 123B
Svinárský p. 41B
?
1
2
3

Kurovice Limestone and Tlumačov Marl. The sedimentary breccias were deposited by repeated gravity flows.

The index species *Caudammina gigantea* and rare calcareous foraminifers, such as *Globotruncana arca, G.* cf. *falsostuarti* and *Reussela szajnochae* were found in the claystone intercalations (Kurovice quarry, No. 4C) and proved the Late Senonian age (Fig. 4). The autochthonous foraminifers of the Rhabdammina–Rzehakina biofacies from claystone intercalations evidence the high detrital input conditions below the CCD.

In the Kurovice quarry the following nannofossils were recovered in the clay matrix of sedimentary breccias (section Nos. 2 and 3), evidencing the Late Coniacian (CC14 Zone with *Micula decussata* and frequent *Marthasterites furcatus*), Early Campanian (CC18 Zone with *Aspidolithus parcus constrictus* and *Arkhangelskiella specillata*) and Late Campanian with *A. cymbiformis* and *Eiffellithus eximius*.

*Hostýn lithofacies zone*

**Kaumberg Formation**

The Kaumberg Formation in the Hostýn zone has a similar lithofacies development as in the Tři kameny zone. Until now, only the foraminiferal Uvigerinammina jankoi Zone evidencing the Late Turonian to Early Campanian age has been identified there.

**Soláň Formation**

The Soláň Formation (Matějka & Roth 1948) of the Hostýn lithofacies zone is formed by medium- to thick-bedded flysch, ranging in age from the Maastrichtian to the Paleocene (Stráník et al., in print). Its Cretaceous sediments are represented by blue-grey, fine- to coarse-grained sandstones prevailing over grey claystones. At locality Valašské Meziříčí No. 12A/94 sediments yielded nannofossils of the Late Campanian age, such as *Arkhangelskiella cymbiformis*, *Neocrepidolithus watkinsii*, *Reinhardtites anthophorus* and *R. levis* and agglutinated foraminifers of the Hormosina gigantea Zone (Fig. 4).

*Tři kameny lithofacies zone*

**Gault Flysch**

Under the term Gault Flysch authors comprehend black-grey mostly non-calcareous thin- to medium-bedded flysch and compare it to the Gault Flysch known from the Rhenodanubicum of the Eastern Alps. The Gault Flysch represents the oldest known sediments of the probably continuous stratigraphic succession in the Rača Unit. Thickness of the strongly tectonized sediments is difficult to estimate. It was mentioned by Bubík et al. (1993) as a distinct lithostratigraphic unit.

The stratigraphic range Hauterivian–Cenomanian is based on agglutinated foraminifers (Figs. 3 and 4). Only the youngest sediments contain calcareous nannoplankton. Assemblages with *Eiffellithus turriseiffelii* and rare *Lithraphidites acutus* were found at locality Tesák (Bubík et al. 1993). Nannofossil associations with *Corollithion kennedyi* and *Microstaurus chiastius* were found in the Mikuluvka section No. 1/6. The above mentioned species are evidence of the CC9 Zone, i.e. the Early Cenomanian.

Dinocysts (H. Leereveld, pers. comm.) prove the Late Aptian to Middle Albian range in the Salajka section No. 9 where species *Gardodinium trabeculosum, Ovoidinium scabrosum* and *Protoellipsodinium spinicristatum* were found, and the Late Albian to Cenomanian range in the Mikuluvka section No. 1/8, documented by *Lithosphaeridium siphoniferum* and *Epelidosphaeridia.*

Foraminiferal assemblages of the Rhabdammina–Rzehakina and Glomospira–Rhizammina biofacies indicate sedimentation in low-oxygen conditions below the CCD.

**Kaumberg Formation**

The Kaumberg Formation occurs in the Hostýn and Tři kameny lithofacies zones. Farther to the SE it was identified only in deep boreholes (Mišík & Jablonský 1991), such as Jarošov-1 (Špička in Hanzlíková 1976) or Jablunka-1 (Pesl et al. 1982). It is characterized mainly by red-brown non-calcareous claystones prevailing over siltstones and fine-grained sandstones. Pelocarbonates, manganese nodules and layers with a manganese content up to 15 % are rarely found (Liebus 1925). Hanzlíková (in Menčík & Pesl 1966) mentioned rare assemblages of agglutinated foraminifers and radiolarians of the Early and middle Cretaceous age from the "Salajka slice" and compared them with microfauna from the Lhota and Godula formations of the Silesian Unit.

The thickness probably does not exceed 300 m and the stratigraphic range has been newly verified from the Turonian up to the Campanian–Maastrichtian.

Green-grey and dark grey intercalations within red-brown claystones with radiolarians and agglutinated foraminifers of Glomospira–Rhizammina biofacies found near Valašská Bystřice (Mikuluvka section No.1/4) can be correlated with the Cenomanian/Turonian boundary (Fig. 4). This is supported also by the presence of the Bulbobaculites problematicus Zone (upper part of the Cenomanian–lower part of the Turonian). The agglutinated assemblage with *Uvigerinammina praejankoi* and *U. jankoi* found in variegated claystones at Rajnochovice locality No. 14/94 indicates the Turonian age. The Uvigerinammina jankoi Zone (upper part of the Turonian–lower part of the Campanian) was identified in red-brown claystones from Salajka (Nos. 6B, 7B, 15B). The co-occurrence of the *Glomospirella grzybowskii* and *Uvigerinammina jankoi* from another outcrop in Salajka (No. 16) allowed a more precise age determination within the lower part of the Campanian.

The upper part of the Kaumberg Formation is formed by medium- to thin-bedded flysch with sporadic layers of red-brown calcareous claystones to marlstones. Nannofossils with *Ceratolithoides arcuatus* (CC21b Zone) accompanied by high-latitude species *Prediscosphaera stoveri* were found at the locality Salajka No. 13. They are evidence of the lower part of the Late Campanian. Foraminiferal assemblages belong to the Hormosina gigantea Zone which is correlated with the Late Campanian–Maastrichtian interval.

Foraminiferal assemblages of the Rhabdammina–Rzehakina biofacies from the Kaumberg Formation of the Rača Unit indicate high detrital input conditions below the CCD.

**Soláň Formation**

The Soláň Formation in the Tři kameny lithofacies zone comprises the Ráztoka and Lukov members (Pesl, unpublished reports). The Cretaceous age was proved in the Ráztoka Member.

The Ráztoka Member (Shaly-sandstone member sensu Pesl 1968) is characterized by the flysch with a changeable content of sandstones and claystones of mostly grey and green colours. Their thickness reaches about 500 m.

At the locality Uzgruň (Pesl & Švábenická 1988), rare calcareous claystones yielded foraminiferal plankton with *Abathomphalus mayaroensis* and nannofossils, such as *Micula murus* (CC25c Zone), *Nephrolithus frequens* and *Micula prinsii* (CC26), all of which give evidence of the Late Maastrichtian age. In addition, the stratigraphically "youngest" nannofossil assemblages contain the so called "survivor species" (sensu Pospichal & Bralower 1992) typical for the Cretaceous/Tertiary boundary sediments (e.g. *Markalius apertus* and *Neocrepidolithus fossus*). The overlying non-calcareous sequence (Uzgruň No. 23) provided agglutinated foraminifers *Rzehakina fissistomata* and *"Trochammina"* sp. 4 sensu Bubík (1995) indicating the Paleocene age (Fig. 4).

## *Bílé Karpaty Unit*

The Bílé Karpaty Unit is divided into the Hluk and Vlára facies developments (Matějka & Roth 1956; Potfaj 1993; Stráník et al. 1995). Both of them represent partial tectonic units. Tectonic slices of the Upper Cretaceous sediments occurring in the front of the Hluk development have a separate position and their relations with the flysch trough of the Bílé Karpaty Unit still remain uncertain.

### *Slices of uncertain tectonic position*

**Púchov Marl**

The Púchov Marl is known from sporadic outcrops in the Hluk area (Stráník et al. 1995). They are characterized by red, highly calcareous claystones and marls. Their thickness has been estimated at more than 100 m. The underlying and overlying beds of the Púchov Marl have not been reliably identified. Lithologically and stratigraphically they correspond to the Púchov Marl of the Pieniny Klippen Belt. They may represent a continuation of the lithologically and stratigraphically identical sediments of the "Hauptklippenzone" of the Wienerwald in Austria (Bubík 1995). According to the biofacies study, Púchov Marl was deposited in bathyal zone mostly between the lysocline and CCD. Planktonic foraminifers and nannofossils give evidence for the Late Campanian and Maastrichtian age (Stráník et al. 1995). Nannofossil assemblages include low- and mid-latitude species (Švábenická 1996).

**Antonínek Formation**

The Antonínek Formation (Vujta et al. 1989) was described in the quarry at the Sv. Antonínek Hill. It is also known from the tectonic slices in the front of the Bílé Karpaty Unit, such as Sudoměřice and Kobylí hlava Hill localities, and boreholes Blatnice M-1 and PVN-10. Antonínek Formation is formed by medium- to thick-bedded flysch with grey claystones and siltstones prevailing over greywacke sandstones and sporadic limestones (Stráník et al. 1995).

The age of the Antonínek Formation was proved to be Campanian–Maastrichtian (Stráník et al. 1995), the underlying and overlying beds were not reliably identified. The thickness has been estimated at more than 100 m.

The autochthonous foraminifers obtained from hemipelagites belong to the Rhabdammina–Rzehakina biofacies. Together with the sporadic foraminiferal plankton and calcareous benthos they are evidence of sedimentation below (close to) the oscillating CCD (Stráník et al. 1995).

### *Hluk development of the Bílé Karpaty Unit*

**Hluk Formation**

The Hluk Formation (Paul 1890) is exposed near Hluk, where it was also found in numerous boreholes. It is characterized by carbonate flysch with black and grey-green claystones, whitish marls and limestones. The thickness of the formation verified by boreholes exceeds 120 m (Stráník et al. 1995).

The Hluk Formation was stratigraphically correlated with the Lower Cretaceous Veřovice Member and Lhoty Formation of the Silesian Unit of the Moravskoslezské Beskydy Mts. (Buday et al. 1963) and with the Wolfpassing and Bartberg formations of the "Nordzone" of the Wienerwald area in Austria (Grün et al. 1972). Lithological and stratigraphic equivalents of the Hluk Formation occur in the "Hauptklippenzone" (Main Klippen Zone) where Kahlenberg and Laab nappes of the Rhenodanubian Flysch contact each other (Stráník et al. 1995).

Sediments contain rich foraminifers, nannofossils, radiolarians and dinocysts. Two stratigraphically different assemblages of benthonic foraminifers were recognized within the Hluk Formation: 1. the older one with *Pseudoreophax cisovnicensis* and *Protomarssonella?* cf. *hauteriviana* indicating the Hauterivian–Barremian interval, 2. the younger one represented by *Plectorecurvoides alternans* may be correlated with the upper part of the Albian to the ?Cenomanian.

Turbidity marls with the older benthonic assemblage (Hluk locality, V3 and V4 boreholes) provided planktonic foraminifers with *Blefuscuina convexa*, *B. excelsa cumulus* and *B. infracretacea occidentalis* (BouDagher-Fadel, pers. comm.), evidence of the Aptian age. The Aptian age is proved also by radiolarians from the Hluk locality No. 16/19 (Ožvoldová, pers. comm.), documented by species *Crucella gavalai* O'Dogherti and *C. hispana* O'Dogherti. On the other hand, nannofossils of the CC5 Zone with *Lithraphidites bollii* and abundant nannoconids indicate the Late Hauterivian–Early Barremian interval and give evidence for the Tethyan bioprovince.

The non-calcareous hemipelagic clays and their autochthonous foraminifers of the Glomospira–Rhizammina and Rhabdammina–Rzehakina biofacies provide evidence of the environment below the CCD.

**Kaumberg Formation**

The Kaumberg Formation is formed mainly by red-brown non-calcareous claystones sporadically enclosing intercalated beds of greywacke sandstones. The thickness is tectonically reduced, estimated at about 100 m. As observed, the upper and lower boundaries of this formation are tectonic in character. The Svodnice Formation may be developed in the superjacent of the Kaumberg Formation in the internal part of the Hluk development of the Bílé Karpaty Unit (Stráník et al. 1995).

The autochthonous assemblages of agglutinated foraminifers prove the Cenomanian–Late Senonian range documented by the Plectorecurvoides alternans (Blatnička R1/10), Ammobaculites problematicus (Mandát Nos. 46 and 56), Uvigerinammina jankoi (Mandát Nos. 20A and 62), and Hormosina gigantea (Mandát Nos. 20, 57 and 65) zones — see Fig. 4. The horizon with green-grey and black-grey intercalations in red claystones giving evidence of the Cenomanian/Turonian boundary (Mandát section No. 56) can be correlated with a similar horizon in the Rača Unit. The presence of the Recurvoides–Paratrochamminoides and Buzasina–Praecystammina biofacies indicates the abyssal zone. The Late Senonian assemblages belong to the Rhabdammina–Rzehakina biofacies characteristic of high detrital input conditions below the CCD.

**Svodnice Formation**

The Svodnice Formation (Pesl 1968) is formed by medium- to thick-bedded flysch with grey coloured calcareous claystones prevailing over fine- to medium-grained greywacke sandstones.

The underlying beds are probably formed by the Kaumberg Formation, with the overlying Nivnice Formation it was observed interfingering within the Upper Paleocene. Its maximum thickness is estimated at 1000 m (Stráník et al. 1995).

The oldest known sediments contain the Late Senonian planktonic foraminifers. Nannofossils with *Lithraphidites quadratus* (CC25c) and *Nephrolithus frequens* (CC26 Zone) enable a more precise classification into the Late Maastrichtian in the Filipovské údolí section. The overlying beds yielded nannofossils of the lowermost part of the Paleocene, such as *Cruciplacolithus primus* (NP1 biochron — No. 16) and *Cruciplacolithus tenuis* (NP2 Zone — No. 32).

The non-calcareous hemipelagic clays contain agglutinated foraminifers of the Rhabdammina–Rzehakina biofacies indicating the high detrital input conditions below the CCD.

*Vlára development of the Bílé Karpaty Unit*

**Kaumberg Formation**

From the Kaumberg Formation of the Hluk development it only differs in its upper part where thin-bedded flysch with mostly non-calcareous claystones are developed. This lithofacies was described by Potfaj (1993) as the Ondrášovec Member. The total thickness reaches about 400 m. Its underlying beds are unknown, its top is represented by a gradual transition into the Javorina Formation (e.g. the Janegov mlyn and Velký Lopeník localities in the Slovak part of the Bílé Karpaty Mts. — Fig. 2). The stratigraphic range is known from the Cenomanian to the Early Maastrichtian (Fig. 4).

Agglutinated foraminifers and the biofacies are similar to the Hluk development with the exception of the absence of the Buzasina–Praecystamina biofacies.

In the upper flysch part calcareous nannofossils were recorded, ranging in age from the uppermost part of the Lower Campanian up to the base of the Maastrichtian. This stratigraphic interval is documented by species *Ceratolithoides aculeus* (CC20 Zone) which was found at locality Janegov mlyn, and by the first occurrences of *Quadrum sissinghii* and *Petrarhabdus copulatus* (CC21 Zone), *Quadrum trifidum* (CC22a Zone), *Reinhardtites levis* (CC22b Zone) and *Prediscosphaera grandis* (CC23 biochrone) at locality Velký Lopeník.

**Javorina Formation**

The fine- to medium-bedded flysch contains fine- to medium-grained greywacke sandstones, mostly non-calcareous claystones and sporadically intercalations of turbidity limestones (Stráník et al. 1989). The thickness is estimated at 750 m, the age is known in the Campanian to the Lower Paleocene interval.

Nannofossils give evidence for the lower part of the Late Campanian up to the Lower Paleocene. The Late Campanian supported by species *Petrarhabdus copulatus* and *Quadrum sissinghii* (CC21 Zone) was found in Javorina section (Fig. 4). The Lower Paleocene (NP2 biochrone) is documented by nannofossils *Cruciplacolithus asymmetricus, C. intermedius* and *C. primus* at Štítná locality No. 42B.

Assemblages of the Rhabdammina–Rzehakina biofacies indicate the high detrital input conditions below the CCD.

**Svodnice Formation**

The Vlára development of the Svodnice Formation is formed, like its Hluk development, by medium- to thick bedded flysch with grey calcareous claystones prevailing over greywacke sandstones.

The lithological transitions from the Javorina Formation into the Svodnice Formation were observed in the vicinity of Štítná (Fig. 2). The oldest known sediments of the Svodnice Formation were found in section No. 29. They contained the Late Maastrichtian nannofossils of the CC26 Zone, such as *Lithraphidites quadratus, Micula murus* and *Nephrolithus frequens* (Fig. 4). In section No. 35 *Micula prinsii* was recovered, giving evidence of the upper part of the CC26 Zone, i.e. the uppermost part of the Late Maastrichtian. Moreover, "survivor nannofossil species" typical for the Cretaceous/Tertiary boundary were also found in these samples, among others *Markalius apertus.*

The biofacies is the same as that in the Hluk development of the Svodnice Formation.

## Discussion

In the authors' opinion, the Kurovice Klippe can be considered a part of the Rača Unit tectonically as well as paleogeographically. The sedimentary breccia represents the proxi-

mal facies unlike the mature turbidites of the same age from the uppermost part of the Kaumberg Formation.

In the Kurovice Klippe, sediments of the Barremian–Lower Coniacian interval have not been identified yet. Although Benešová et al. (1962) described the Albian in the Kurovice quarry on the basis of the presence of *Rothina silesica (=Caudammina crassa)* and *Globigerinella (=Globigerinelloides) ultramicra*, according to the present knowledge, these taxa are of no stratigraphic value in the Cretaceous. The absence of the Barremian–Lower Coniacian sediments can be explained by submarine erosion.

The Púchov Marl is traditionally attributed to the Hluk development of the Bílé Karpaty Unit (Potfaj 1993; Stráník et al. 1995). Its foraminiferal fauna of the Marssonella biofacies and the absence of plankton are evidence of sedimentation in the bathyal zone mostly between the lysocline and the CCD. The stratigraphically equivalent foraminifers of the Kaumberg Formation indicate the bathyal to abyssal zones below the CCD. Considering this contrast, Bubík (1995) detached the Púchov Marl from the Hluk area and compared it to the variegated marls of the "Hauptklippenzone" of the Wienerwald in Austria. The occurrence of the Púchov Marl in the above mentioned areas suggests close relations to the Pieniny Klippen Belt. This speculation is supported by nannofossil assemblages formed only by cosmopolite and Tethyan species not found anywhere else in the Upper Cretaceous sediments of the Magura Group of nappes (Švábenická 1996).

The paleogeographical classification of the Antonínek Formation remains questionable. It is considered a part of the Hluk development of the Bílé Karpaty Unit by Stráník et al. (1995) while Bubík (1995) regards it as a separate succession on the basis of biofacies study. An abrupt lateral substitution by the stratigraphically equivalent red-brown claystones of the Kaumberg Formation is improbable.

The mutual relations of the formations in the Hluk development of the Bílé Karpaty Unit are rather problematic, as their boundaries have not been identified yet. No indications of the transition between the Kaumberg and the Svodnice formations (like variegated intercalated beds) have been observed yet. The lithostratigraphic boundary of the Hluk and Kaumberg formations has not been observed either. In contrast, in the Vlára development a slow lithological transition of the flyschoid upper part of the Kaumberg Formation into the Javorina Formation was found and there were also transitions from the Javorina Formation into the Svodnice Formation.

According to the present knowledge, the biofacies distribution in the Hluk development of the Bílé Karpaty unit is evidence of a paleobathymetric trend from the lower bathyal in the Barremian–Albian interval to the abyssal in the Cenomanian–Campanian (?Maastrichtian) back to the lower bathyal since the Maastrichtian (Bubík 1995). The spreading of abyssal biofacies as well as the presence of extremely distal lithofacies reflect deepening of the depositional area in the Cenomanian to the Campanian. The disappearance of the abyssal biofacies could have been induced also by the fall of the CCD generally supposed in the Upper Senonian.

Results of the biofacies study indicate that the depositional area of the Hluk development of the Bílé Karpaty Unit was probably deeper than the flysch trough of the Rača Unit in the period of the maximum depth in the Turonian to Early Senonian.

In the authors' opinion, the transition from the Lower Cretaceous dark and black facies rich in total organic carbon content to red-brown sediments of the Upper Cretaceous was probably caused by a widely distributed paleoceanographic event. This change was also observed in the Silesian Unit (Menčík 1983), Pieniny Klippen Belt (Birkenmajer 1977) and in the North Atlantic Basin (Jansa et al. 1979). In the non-calcareous sediments of the Hluk development of the Bílé Karpaty Unit, this event was observed within the Plectorecurvoides alternans Zone (upper part of the Albian–lower part of the Cenomanian). Although the transition from the Hluk Formation to the Kaumberg Formation is conventionally placed at the Albian/Cenomanian boundary (Stráník et al. 1995), the presence of the Cenomanian in the upper part of the Hluk Formation is possible (Bubík 1995, Fig. 1, Appendix 1). In the Rača Unit, the continuation of the black flysch sedimentation in the Early Cenomanian is proved by the presence of the CC9 nannofossil zone.

## Conclusions

— On the basis of new litho- and biostratigraphic study, the Cretaceous was proved in the flyschoid lithofacies zones of the Rača and Bílé Karpaty units from the Barremian to the Maastrichtian (Fig. 5).

— The oldest Cretaceous sediments (Berriasian–Valanginian) are characterized by carbonate development. Carbonate turbidites of the Tlumačov Marl may be correlated with the similar stratigraphic equivalents of the Silesian Unit (Tešín Limestone).

— From the paleogeographical point of view, the Cretaceous of the Kurovice depositional area is considered to be a part of the Magura Basin.

— During the Cenomanian, the dark sediments in the Rača Unit were substituted by variegated ones, which are characterized by red-brown non-calcareous claystones. This event is thought to be of a global character.

— According to the biofacies study, the depositional area of the Hluk development of the Bílé Karpaty Unit was probably deeper within the Uvigerinammina jankoi Zone (Turonian–Lower Campanian) than the flysch trough of the Rača Unit.

— The Cretaceous/Tertiary boundary lies within the lithic flysch sediments both in the Rača and Bílé Karpaty units.

— Lower Cretaceous sediments contain nannofossils mainly of the Tethyan bioprovince. In the Upper Cretaceous (especially in the Campanian and Maastrichtian), common occurrences of high- and low-latitude nannofossils show the influence of both Boreal and Tethyan bioprovinces on the Magura depositional area. Tectonic slices at the front of the Bílé Karpaty Unit extend beyond this model: the Púchov Marl with a typical Tethyan nannofossil assemblage and, on

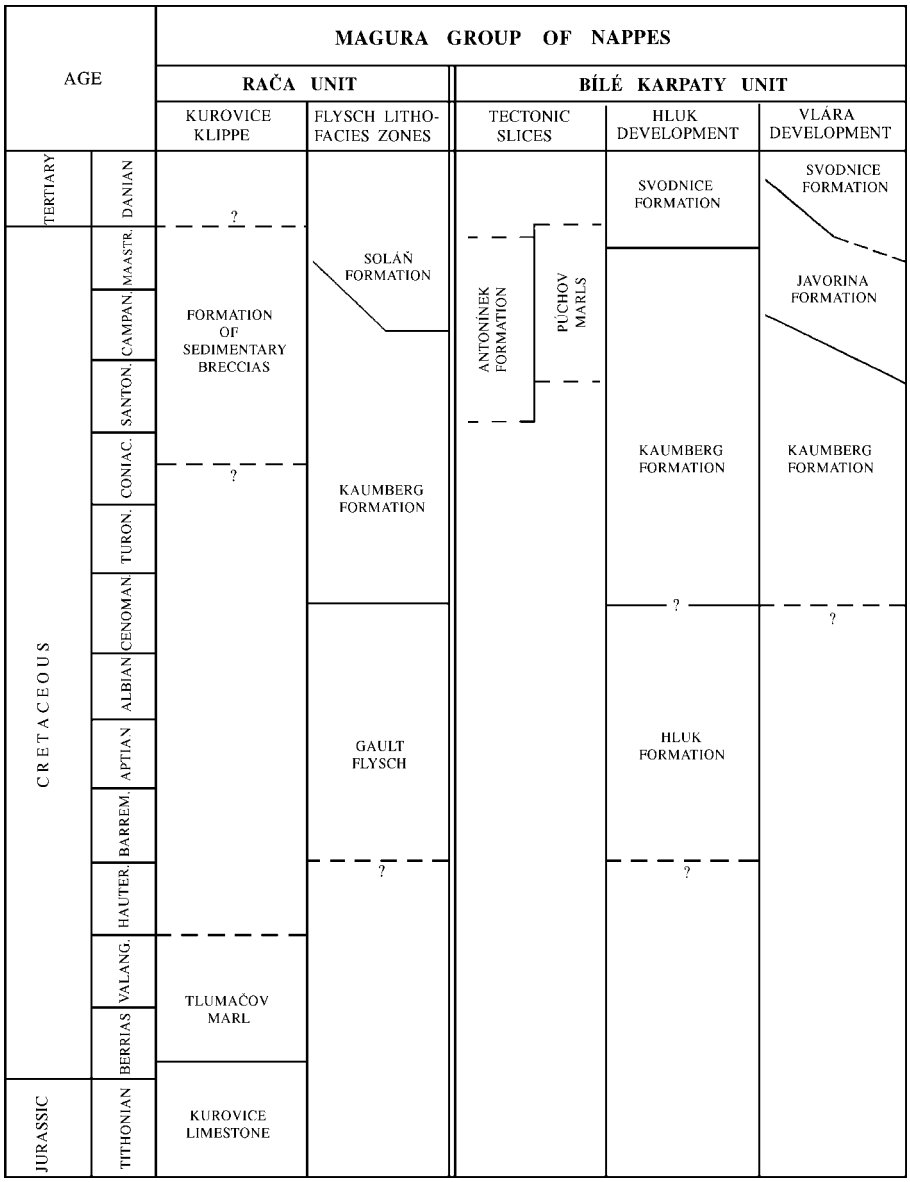


**Fig. 5.** Stratigraphic correlation chart of the Cretaceous sediments of the Magura Group of nappes.

the other hand, the Antonínek Formation where high-latitude nannofossils of the Boreal bioprovince prevail.

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## Appendix No. 1

List of foraminifers mentioned in the text, arranged in alphabetical order by generic names.

*Planktonic taxa*

*Abathomphalus mayaroensis* (Bolli 1951)
*Blefuscuiana convexa* (Longoria 1974)
*Blefuscuiana excelsa cumulus* (Banner, Copestake & White 1993)
*Blefuscuiana infracretacea occidentalis* (BouDagher-Fadel et al. 1995)
*Globigerinelloides ultramicra* (Subbotina 1949)
*Globotruncana arca* (Cushman 1926)
*Globotruncana falsostuarti* Sigal 1952
*Gorbachikella anteroapertura* (BouDagher-Fadel et al. 1995)
*Gorbachikella kugleri* (Bolli 1959)
*Praehedbergella handousi* (Salaj 1984)

*Benthic taxa*

*Caudammina crassa* (Geroch 1966)
*Caudammina gigantea* (Geroch 1960)
*Glomospirella grzybowskii* (Jurkiewicz 1960)
*Plectorecurvoides alternans* Noth 1952
*Protomarssonella? hauteriviana* (Moullade 1961)
*Pseudoreophax cisovnicensis* Geroch 1961
*Reussella szajnochae* (Grzybowski 1896)
*Rzehakina fissistomata* (Grzybowski 1901)
*Uvigerinammina jankoi* Majzon 1943
*Uvigerinammina praejankoi* Neagu 1990

## Appendix No. 2

List of calcareous nannofossils mentioned in the text, arranged in alphabetical order by generic names.

*Arkhangelskiella cymbiformis* Vekshina 1959
*Arkhangelskiella specillata* Vekshina 1959
*Aspidolithus parcus constrictus* (Hattner et al. 1980) Perch-Nielsen 1984
*Ceratolithoides aculeus* (Stradner 1961) Prins & Sissingh in Sissingh 1977
*Ceratolithoides arcuatus* Prins & Sissingh in Sissingh 1977
*Conusphaera mexicana* Trejo 1969
*Corollithion kennedyi* Crux 1981
*Cruciplacolithus asymmetricus* van Heck & Prins 1987
*Cruciplacolithus intermedius* van Heck & Prins 1987
*Cruciplacolithus primus* Perch-Nielsen 1977
*Cruciplacolithus tenuis* (Stradner 1961) Hay & Mohler in Hay et al. 1967
*Eiffellithus eximius* (Stover 1966) Perch-Nielsen 1968
*Eiffellithus turriseiffelii* (Deflandre in Deflander & Fert 1954) Reinhardt 1965
*Lithraphidites acutus* Verbeek & Manivit in Manivit et al. 1977
*Lithraphidites bollii* (Thierstein 1971) Thierstein 1973
*Lithraphidites quadratus* Bramlette & Martini 1964
*Markalius apertus* Perch-Nielsen 1979
*Marthasterites furcatus* (Deflandre in Deflandre & Fert 1954) Deflandre 1959
*Micrantholithus speetonensis* Perch-Nielsen 1979
*Microstaurus chiastius* (Worsley 1971) Grün in Grün & Allemann 1975
*Micula decussata* Vekshina 1959
*Micula murus* (Martini 1961) Bukry 1973
*Micula prinsii* Perch-Nielsen 1979
*Nannoconus globulus* Brönnimann 1955
*Neocrepidolithus fossus* Romein 1979
*Neocrepidolithus watkinsii* Pospichal & Wise 1990
*Nephrolithus frequens* Górka 1957
*Petrarhabdus copulatus* (Deflandre 1959) Wind & Wise in Wise 1983
*Prediscosphaera grandis* Perch-Nielsen 1979
*Prediscosphaera stoveri* (Perch-Nielsen 1968) Shafik & Stradner 1971
*Quadrum sissinghii* Perch-Nielsen 1984
*Quadrum trifidum* (Stradner in Stradner & Papp 1961) Prins & Perch-Nielsen in Manivit et al. 1977
*Retacapsa angustiforata* Black
*Reinhardtites anthophorus* (Deflandre 1959) Perch-Nielsen 1968
*Reinhardtites levis* Prins & Sissingh in Sissingh 1977
*Rhagodiscus nebulosus* Bralower in Bralower et al. 1989
*Zeugrhabdotus erectus* (Deflandre in Deflandre & Fert 1954) Reinhardt 1965

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