Mineralia Slovaca, Web ISSN 1338-3523, ISSN 0369-2086, https://doi.org/10.56623/ms.2025.57.1.4
57, 1 (2025), 59 – 80, © Authors 2025. CC BY 4.0

Santonian-Campanian marly and biodetritic facies in the Púchov Formation in the Orava sector of the Pieniny Klippen Belt (Slovakia)

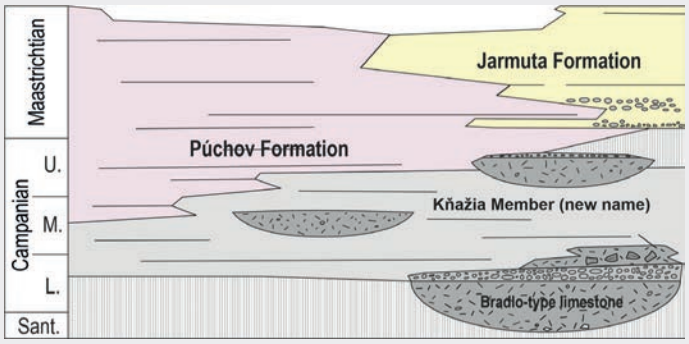
ONDREJ PELECH[1], ŠTEFAN JÓZSA[2] and MÁRIO OLŠAVSKÝ[3]

[1]State Geological Institute of Dionýz Štúr, Mlynská dolina 1, SK-81704, Bratislava 1, Slovak Republic; ondrej.pelech@geology.sk
[2]Comenius University, Faculty of Natural Sciences, Department of Geology and Paleontology, Ilkovičova 6, SK-84215, Bratislava, Slovak Republic
[3]State Geological Institute of Dionýz Štúr, Zelená 5, SK-97404, Banská Bystrica, Slovak Republic

Abstract: The Pieniny Klippen Belt is characterized by the block-in-matrix fabric with Jurassic to Lower Cretaceous rigid klippen embedded in less competent Upper Cretaceous flysch and marlstone matrix. The studied area is located in the Orava sector of the Pieniny Klippen Belt. Based on results of recent geological mapping and biostratigraphic analysis, the paper distinguishes a new formal lithostratigraphic unit – the Kňažia Member/Beds composed dominantly of white marly limestone, with lenses of biodetritic limestone, calcarenite to conglomerate of the Bradlo-type limestone. The new member occurs at several localities along the studied Orava sector of the Pieniny Klippen Belt, with the largest volumes north of Dolný Kubín (Opálené Hill) and Podbiel (Lučivný vrch Hill). Both lithostratigraphic units contain relatively abundant planktonic foraminifera co-occurring in the middle Campanian Contusotruncana plummerae Zone. The interbedding biodetritic limestones correlated with the Bradlo-type limestone are rich in *Pseudosiderolites* spp. and contain Santonian–Campanian rudists. The Kňažia Member represents the lower part of the pelagic basinal sediments within the Upper Cretaceous Púchov Formation. The occasional bodies of allodapic calcarenites of the Bradlo-type limestone represent channel fills composed of shallow water carbonate detritus.

Key words: Upper Cretaceous, geological mapping, foraminifera, microfacies, Kňažia Member, Bradlo-type limestone

Graphical abstract



Highlights

- Occurrence of upper Santonian-Campanian white marly limestone and biodetritic limestone within the Púchov Formation is documented in the Orava sector of the Pieniny Klippen Belt
- The white marly limestones – wackestones (planktonic foraminiferal biomicrites) are herein defined as the Kňažia Member (new name)
- The grey packstones to grainstones (calcarenites to microconglomerates or breccia) formerly known as the "Lučivný vrch facies" are correlated with the Bradlo Limestone

Introduction

The Pieniny Klippen Belt (PKB) is a long and narrow lithotectonic unit forming boundary of Cenozoic accretionary wedge of the Carpathian Flysch Belt in the North and Internal Western Carpathian orogenic zones formed by the Tatric, Fatric and Hronic units in the South (Andrusov, 1938; Birkenmajer, 1986; Mišík, 1997; Lexa et al., 2000; Bezák et al., 2008, 2009; Plašienka, 2018a, b). The geological structure of the PKB is characterized by the block-in-matrix fabric, represented by rigid Jurassic or Lower Cretaceous limestone klippen tens of meters to kilometre large, surrounded by less competent Cretaceous flysch and marlstones (often referred to as "klippen cover"). The Jurassic to Cretaceous klippen are divided based on the lithofacial character into several contrasting successions, namely the shallow water Czorzstyn succession and the deep-water Kysuca-Pieniny succession (Andrusov, 1938, 1959).

The studied area is located in the Orava sector of the PKB (Fig. 1A). From the northern side the PKB rocks are bounded by the Magura Group of Nappes and from the south by the rocks of the Central Carpathian Paleogene Basin. The studied area is largely composed of Upper Cretaceous "klippen cover", mostly consisting of the Turonian Snežnica Formation and Coniacian–Santonian Sromowce Formation reaching thickness 100–500 m. Both formations are represented by grey quartz-carbonate flysch with interbedded conglomerate bodies. The conglomerates locally acquire thickness up to 100 m (e.g., Marschalko & Samuel, 1978; Marschalko, 1986). Due to similar lithology and deformation in the PKB mélange, it is usually not possible to distinguish between the Snežnica and Sromowce formations without biostratigraphic knowledge, therefore they are treated together in this paper.

The "klippen cover" formations contain scattered limestone klippen belonging mainly to the Kysuca and Orava/Podbiel successions. The oldest rocks are represented by Lower Jurassic quartz sandstones of "Gresten Beds" recently named as Dutkov vrch Formation (Plašienka et al., 2021). Their continuity to the younger parts of the sedimentary sequence is unclear. The only larger klippe with continual sedimentary succession from Lower Jurassic to Cretaceous is the Červená skala Hill near Podbiel village (Fig. 1C; Haško, 1978; Borza et al., 1993). The basal part of the sedimentary sequence is composed of the Sinemurian–Pliensbachian spotted marlstone and limestone of the Allgäu Formation and Kozinec Beds, Toarcian (lower) red nodular limestone; and grey, red and green radiolarites of the Czajakowa Formation of Oxfordian–Kimmeridgian age. The middle part is represented by the Czorsztyn Formation – (upper) red nodular limestones of the Kimmeridgian–Tithonian age and the Tithonian–Barremian grey and white calpionellid and nannoconid limestones of the Pieniny Formation. The upper portion of the Pieniny Fm. gradually passes into the Aptian–Albian grey shales and siltstones of the Koňhora or Kapuśnica Formation, which is followed by the Maastrichtian flysch, an analogy of the Jarmuta Formation.

Unlike the aforementioned klippe which is the typical representative of the Orava/Podbiel succession; the prevailing klippen are composed of the Kysuca succession that differs by the presence of grey shales and spotted limestones of Posidonia (Harcygrund) and Supraposidonia (Podzamcze) formations of Aalenian–Callovian age (e.g., Andrusov, 1931a, b; Gross et al., 1993).

The Czorsztyn succession is preserved only locally, especially on the northern margin of the PKB. It is represented mainly by the Upper Cretaceous pink pelagic marlstones and limestones of the Púchov Formation with small klippen of red nodular limestones of Upper Jurassic Czorsztyn Formation.

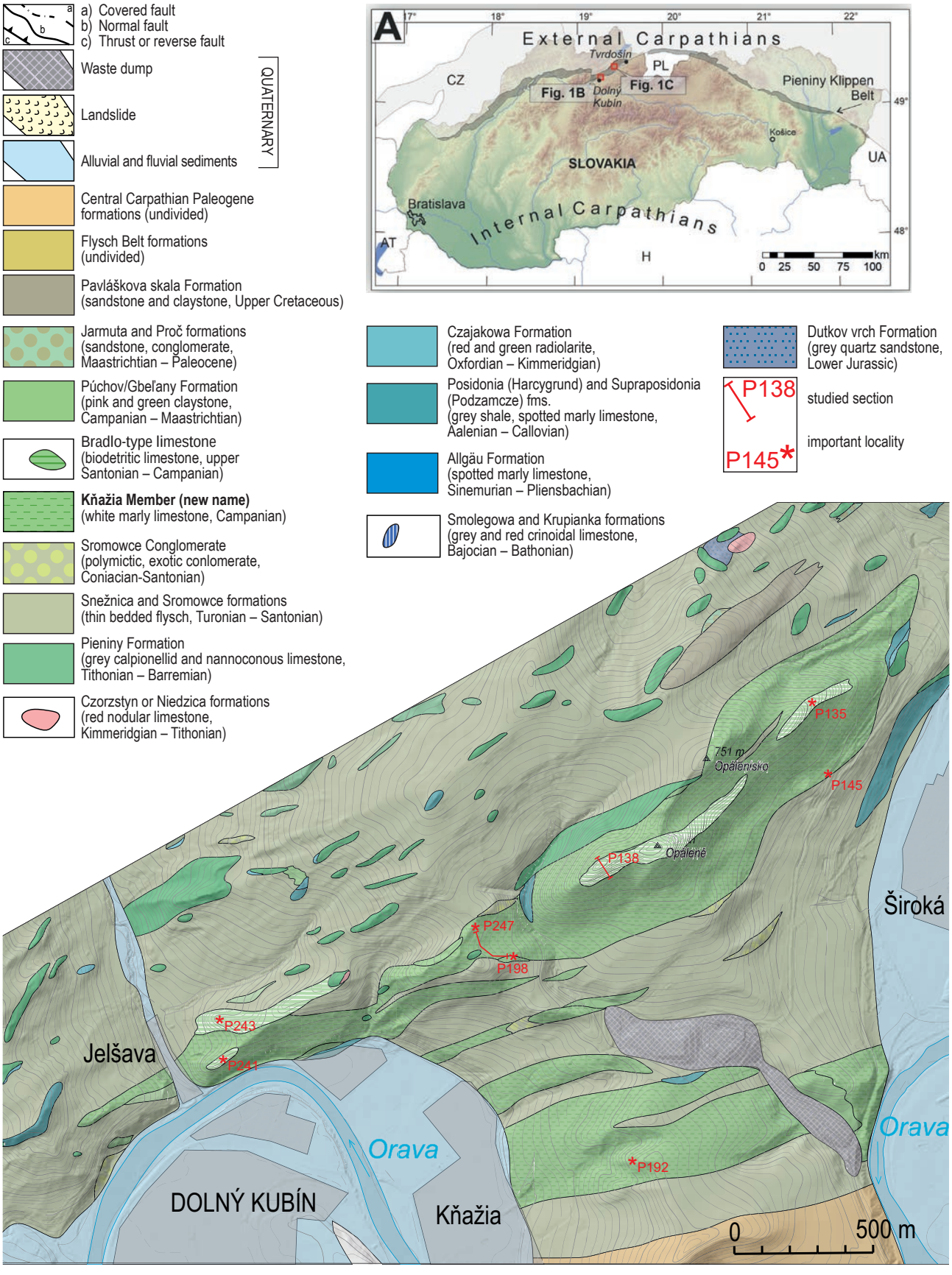
Separate type of sequence is represented by the Upper Cretaceous Pavláškova skala Formation developed in sandstone and variegated facies, often associated with Jarmuta and Proč fms. (Andrusov, 1938; Bezák et al., 2009; Teťák et al., 2025), which can be correlated with Šariš succession (e.g., Plašienka et al., 2012; Plašienka et al., 2021, however with certain differences compared to the cited works). It should be noted that both formations have nearly identical lithology and differ only in age, as the Jarmuta Fm. is Maastrichtian while the Proč Fm. is Paleocene–early Eocene. Therefore, both formations are not separated in this work.

The main aim of this paper is to describe in more detail the peculiar lithofacies of the Púchov Fm. present in the studied area, especially in the area between Dolný Kubín town and Oravský Podzámok – Široká settlement and in the area of the Lučivný vrch Hill (841 m a.s.l.) north of Podbiel village. The particularly important sections are summarized in the Tab. 1 and Fig. 1.

Overview of previous research

The Late Cretaceous lithofacies of the PKB are usually divided into the siliciclastic sandy turbidites and conglomerates (Snežnica and Sromowce fms.) and variegated pelagic marlstones (Púchov Fm.), probably representing the paleotopographic heights without coarser siliciclastic input, usually unaffected by mass wasting processes (Marschalko, 1986).

The term Púchov Beds or Púchov Marlstone was originally introduced in the PKB in the Middle Váh Valley area for red and grey marlstones of Late Cretaceous age (Stur, 1860, p. 115). It is a typical representant of the "couches rouges" facies, also known as Cretaceous Oceanic Red Beds (CORB, Hu et al., 2006). Today, however, the pink marlstones do not crop out in the Púchov town; and in the wider area (Vieska, Dohňany and Ihrište), several types of Cretaceous red marlstones with different stratigraphic age were defined (Kantorová & Andrusov, 1958; Andrusov, 1959; Andrusov & Scheibner, 1960; Salaj, 1990; Mello et al., 2011). Moreover, several other names for the Cretaceous red and variegated marlstones were defined in the PKB (Albian Chmielowa Beds, Turonian Kysuca Beds, Cenomanian Lalinok Beds, Campanian–Maastrichtian Gbeľany Beds; Cenomanian–Campanian Jaworki Fm. etc., see Birkenmajer, 1977; Haško & Polák, 1978, 1979; Gross et al., 1993; Potfaj, 1993; Stráník et al., 1995; Bezák et al., 2009; Plašienka et al., 2012, 2021). Some of aforementioned terms overlap, or are used for the same rocks of the same age but in different tectonic units and are likely to require revision in the future.


a) Covered fault
b) Normal fault
c) Thrust or reverse fault
Waste dump
Landslide
Alluvial and fluvial sediments
QUATERNARY
Central Carpathian Paleogene formations (undivided)
Flysch Belt formations (undivided)
Pavláškova skala Formation (sandstone and claystone, Upper Cretaceous)
Jarmuta and Proč formations (sandstone, conglomerate, Maastrichtian – Paleocene)
Púchov/Gbeľany Formation (pink and green claystone, Campanian – Maastrichtian)
Bradlo-type limestone (biodetritic limestone, upper Santonian – Campanian)
Kňažia Member (new name) (white marly limestone, Campanian)
Sromowce Conglomerate (polymictic, exotic conlomerate, Coniacian-Santonian)
Snežnica and Sromowce formations (thin bedded flysch, Turonian – Santonian)
Pieniny Formation (grey calpionellid and nannoconous limestone, Tithonian – Barremian)
Czorzstyn or Niedzica formations (red nodular limestone, Kimmeridgian – Tithonian)
A
External Carpathians
Tvrdošín
PL
CZ
Fig. 1B
Dolný Kubín
Fig. 1C
Pieniny Klippen Belt
Košice
SLOVAKIA
UA
Bratislava
Internal Carpathians
AT
H
km
0 25 50 75 100
17° 18° 19° 20° 21° 22°
49°
48°
Czajakowa Formation (red and green radiolarite, Oxfordian – Kimmeridgian)
Posidonia (Harcygrund) and Supraposidonia (Podzamcze) fms. (grey shale, spotted marly limestone, Aalenian – Callovian)
Allgäu Formation (spotted marly limestone, Sinemurian – Pliensbachian)
Smolegowa and Krupianka formations (grey and red crinoidal limestone, Bajocian – Bathonian)
Dutkov vrch Formation (grey quartz sandstone, Lower Jurassic)
P138
studied section
P145*
important locality
P135
751 m
Opálenisko
P145
Opálené
P138
P247
P198
Široká
P243
Jelšava
P241
Orava
P192
Orava
DOLNÝ KUBÍN
Kňažia
0
500 m

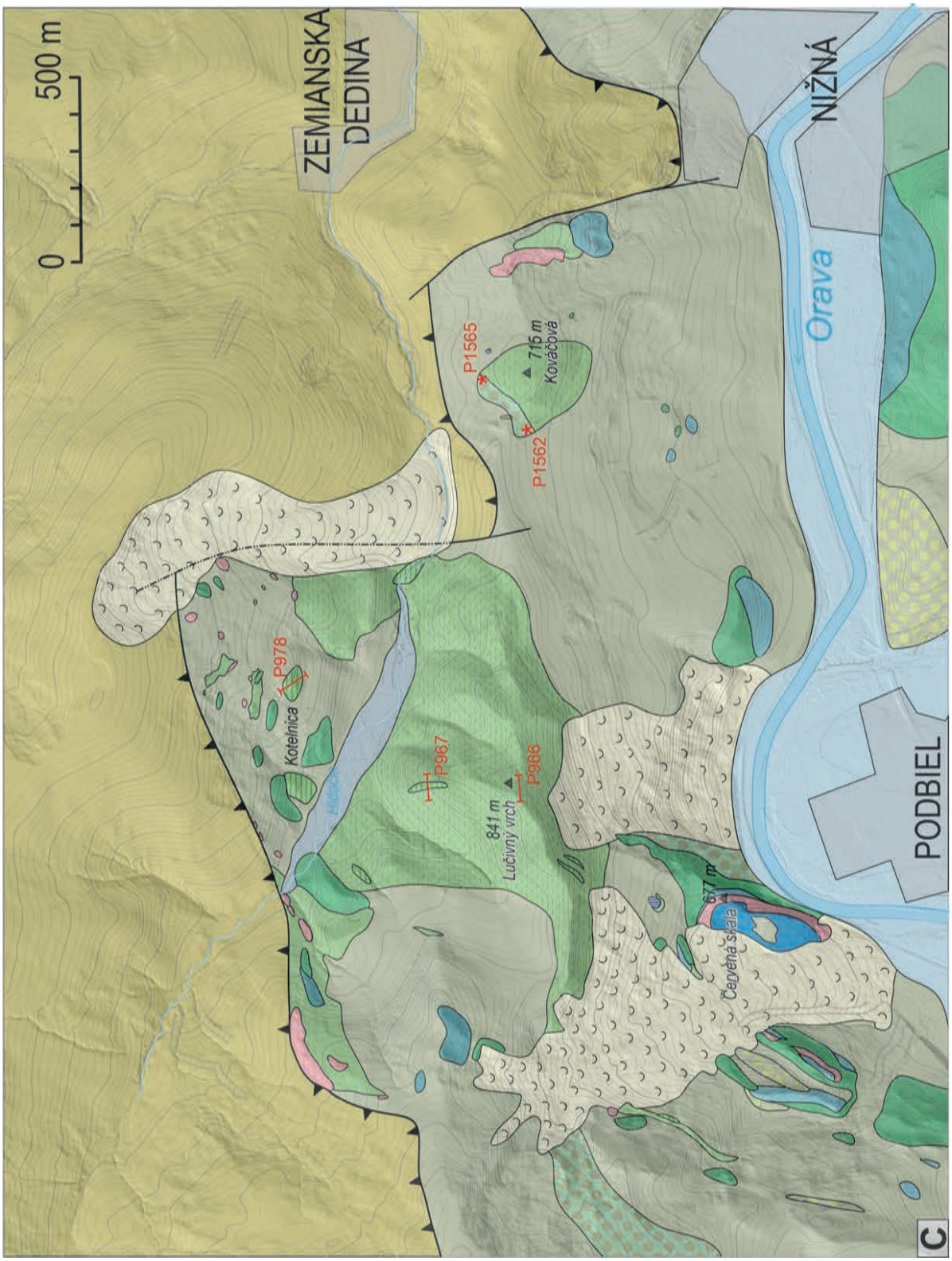


Fig. 1. A – Location of studied area. B – Geological map of the Opálené Hill surroundings, north of the Dolný Kubín town. C – Geological map of the Lučivný vrch Hill surroundings, north of the Podbiel village. Geological maps based on Andrusov (1931a, b) and Teťák et al. (2024, 2025).

Tab. 1

Description and location of main localities and important sections with studied samples or description in the text

Number	Description	Locality	WGS X (N) [°]	WGS Y (E) [°]
P135	Outcrops of marly limestone and calcarenite in the ridge (Kňažia Mb.)	NE ridge of Opálenisko Hill	49.250263	19.332689
P138	Outcrop of calcarenite between the white marly limestones (Kňažia Mb.)	W Ridge of Opálené Hill	49.246311	19.325987
P145	Debris in the slope under power lines (Kňažia Mb.)	W of Široká (Oravský Podzámok)	49.248277	19.334142
P192	Debris of white marly limestone (Kňažia Mb.)	Ridge N of Kňažia	49.2362447	19.3256996
P198	Outcrop white marly limestone (Kňažia Mb.)	Road cut NW of Kňažia	49.2424821	19.3194897
P241	Outcrop of calcarenite between the white marly limestones (Kňažia Mb.)	Ridge E of Jelšava	49.239117	19.3057518
P243	Outcrop of calcarenite between the white marly limestones (Kňažia Mb.)	Ridge E of Jelšava	49.240412	19.305832
P247	Outcrop white marly limestone (Kňažia Mb.)	Road cut NW of Kňažia	49.2434883	19.3176626
P529	Outcrop of pink marlsotne (Púchov Fm.)	Ridge N of Horná Lehota	49.2811111	19.4070028
P564	Outcrop of white marly limestone (Kňažia Mb.)	Riedky diel ridge NW of Malý Bysterec	49.216861	19.258994
P579	Outcrop of calcarenite and white marly limestone (Kňažia Mb.)	Slope above cemetery near Beňova Lehota	49.2334951	19.2603735
P785	Outcrop of calcarenite within the white marly limestones (Kňažia Mb.)	N of Červená skala	49.3170011	19.4822077
P789	Outcrop of calcarenite (Bradlo-type limestone) with intraclasts of red Púchov-type marlstone	Lučivný vrch Hill	49.3172842	19.477742
P792	Debris of calcarenites and white marly limestones (Kňažia Mb.)	Lučivný vrch Hill	49.3174840	19.4762231
P819	Outcrop of calcarenite (Bradlo-type limestone)	Vyšné skalky, N of Podbiel	49.3144436	19.4725977
P966	Forest road cut with white marly limestone and calcarenite interbeds (Kňažia Mb.)	Lučivný vrch Hill	49.3186335	19.4855090
P967	Calcarenite body between the marly limestones (Kňažia Mb.)	Ridge N of Lučivný vrch Hill	49.3209594	19.4858471
P978	Calcarenite with rudists (Bradlo-type limestone) and exotic conglomerate	N slope of Hldočín	49.3247027	19.4897558
P1067	Calcarenite (Bradlo-type limestone) with exotic conglomerate	Cut of Oravica river	49.3597029	19.6341564
P1087	Debris of white marly limestone (Kňažia Mb.)	W of Trstená collective farm	49.3525679	19.6065869
P1101	Debris of white marly limestone (Kňažia Mb.)	Cut of Zábiedovčík brook, SE of Tvrdošín	49.3476157	19.5898878
P1373	Debris red Púchov-type marlstones, white marly limestone (Kňažia Mb.), calcarenite and conglomerates	Repiská, elevation point 730 m a.s.l.	49.2390682	19.2740471
P1562	Outcrop of calcareous sandstones, Jarmuta Fm.	Road cut S of Kováčová Hill	49.3183562	19.5006571
P1565	Debris of carbonate conglomerate to breccia, with Pieniny Fm. radiolarian limestone clasts, Jarmuta Fm.	NW slope of Kováčová Hill	49.3195973	19.5024442
P1653	Outcorp of Bradlo-type limestone calcarenite with exotic conglomerate	E of elevation point 675 m a. s. l. (Dolný Kubín-Veľký Bysterec)	49.2342132	19.2799016

The studied rock complexes of the Upper Cretaceous variegated marls with thin sandstone interbeds were originally imaged on the pre-World War II 1:25 000 geological map of the studied region as "*upper Senonian of the Klippen belt (Púchov Beds)*" [Czech: "*svrchní senon útesového pásma (púchovské vrstvy)*]" (Andrusov, 1931a, b, 1938). The Santonian–Campanian biodetritic limestone with shallow water rudist macrofauna accompanying the exotic conglomerates was documented in the area West of Zemianska Dedina (Kühn & Andrusov, 1942; Andrusov, 1959). Later an inconspicuous map showed bodies of "*organodetritic limestones of the Gbeľany Beds*" in the area of the Opálené Hill north of the Dolný Kubín town and documented Late Cretaceous resedimentation (Marschalko et al., 1979). A brief description of "*a facies of variegated Púchov marlstones with interbeds of turbiditic sandstones, organodetritic sandstones and olistolith bodies of the Gbeľany Beds*" was provided, however their occurrence was not localized neither in the text of the monograph nor in the attached map (Haško in Gross et al., 1993). Another brief description was provided from the road cut near Jelšava (Dolný Kubín; Jablonský & Halásová, 1994), where tectonic imbrication of 4 thrust sheets in the studied section interpreted as tectonic mélange was documented. Finally, benthic foraminiferal microfauna of biodetritic sandstones in the Homôľka Hill (in fact the Opálené Hill) and the Lučivný vrch Hill (north of Podbiel) areas were studied, and the term "*Lučivný vrch facies*" (Slovak: "*vývoj Lučivného vrchu*") was proposed (Salaj & Köhler, 2001).

The age of the Púchov Fm. in the studied region is determined by the nanoplankton and foraminiferal microfauna as Campanian–Maastrichtian (Salaj in Gross et al., 1980; Gross et al., 1993; Jablonský & Halásová, 1994), however, identical pink marlstone interbeds within the Snežnica and Sromowce fms. are of Cenomanian and Turonian age (Matějka & Hanzlíková, 1962; Potfaj et al., 1981; Gross et al., 1984).

Methods

The geological mapping of the region was carried out in terms of a standard methodology, and according to the Directive of the Ministry of the Environment of Slovak Republic No. 4/1996-3.1. for the compilation of basic geological maps and explanatory notes at scale 1:25 000 and regional geological maps at scale 1:50 000. The present work is based on the results of LiDAR assisted detailed geological mapping at scale 1:10 000 (e.g., Liščák et al., 2022). The accuracy of the GNSS equipment used for location of the documentation points was within 5 m. The presented biostratigraphic results are based on the microfacies analysis of the 24 thin sections by standard methods (e.g., Flügel, 2010). The taxonomy and biostratigraphy of planktonic foraminifera is based on Robaszynski et al. (1984), Caron (1995), Premoli Silva & Verga (2004), Falzoni & Petrizzo (2011) and Coccioni & Premoli Silva (2015).

The formal definition of new lithostratigraphic unit follows the recommendations of the International Stratigraphic Guide (Michalík et al., 2007; Salvador, 2013).

Results

The geological mapping in the Orava sector of the PKB revealed new knowledge about the less known lithofacies of the Upper Cretaceous Púchov Fm. Especially, the correct assignment of the white marly limestones – newly designated Kňažia Member/Beds (new name), posed an initial problem. White to grey limestones were initially considered as possible variety of the Jurassic Kozinec Limestone. However, doubts were cast due to the absence of other Jurassic facies that commonly accompany the Kozinec Limestone, as well due the presence of calcarenites, quartz-carbonate sandstones, and the frequent association with the variegated marlstones of the Púchov Fm. The problem was definitively solved by a microfacies study, which confirmed the presence of Late Cretaceous planktonic foraminifera.

Púchov Formation

The typical Púchov Fm. consists of pink to brick-red, rarely green or grey, marlstone to clayey limestone or clayey shale. The weathered surface of the marlstone to limestone may contain weathered planktonic foraminifera observable under a magnifying glass. Weathered marlstones sometimes form red eluvial clay which, in cases of poor exposure, represents the only indication of their presence. Deformed marlstone is often penetrated by slickensides, and numerous calcite accretionary steps which are relatively resistant to weathering and are preserved in the debris as well. The formation may also contain interbeds of medium-bedded (5–30 cm thick beds) quartz-carbonate sandstones. The red Púchov marlstones are rich in planktonic foraminifera (e.g., sample P529, Tab. 2). The lower part of the formation in the studied area, is often interbedded with white marly limestones, which are defined in this paper as the Kňažia Member (new name) and the associated white biodetritic limestones are correlated with the Bradlo-type limestones. The Púchov Fm. is first metres to 100 metres thick and forms separate bodies or thinner interbeds in the "klippen cover" flysch (Snežnica and Sromowce fms.). The red Púchov-type marlstone interbeds in the Snežnica and Sromowce fms. can be of a dual character. More often, they are in a normal stratigraphic contact. However, in some cases the alternation is clearly result of thrusting and imbrication.

The uppermost part of the Púchov Fm. locally includes grey and variegated marlstones, breccia with olistoliths of the Záskalie Breccia, that represents the youngest, syn-orogenic deposits of the formation.

According to the results of geological mapping, the tectonic position of the studied Púchov Fm., including the newly defined Kňažia Mb. with the Bradlo-type limestone, is associated with the rocks of deep-water Orava/Podbiel and Kysuca successions.

Kňažia Member (new name)

Lithology: Prevailing portion of the lithostratigraphic unit is formed by thin- to thick-bedded white to pale grey, fine- to medium-grained pelagic limestone (calcilutite; Figs. 2A–B, F and 3) to marlstone. The microfauna consists predominantly of planktonic foraminifera. It can also be characterized as a white indurated variety of the Púchov Marlstone. The marly limestones locally contain interbeds of variably thick (up to 4 m) thin- to medium-bedded biodetritic limestones – calcarenites. The calcarenites are distinguished as a separate Bradlo-type limestone, which is described below. The white marly limestones also contain up to first meters thick interbeds of pink and green Púchov-type marlstone and up to 1 m thick quartz-carbonate sandstone beds.

Microfacies are represented by micritic limestones (wackestone to packstone) with abundant cross sections of planktonic foraminifera with globular chambers and representatives of the family Globotruncanidae, described hereinafter (Figs. 6A–B, 8 and 9). Locally fragments of thin-shelled bivalves and echinoderm fragments are present. Rare spotted texture is a result of bioturbation.

White marly limestone with planktonic foraminifera may macroscopically resemble the Lower Cretaceous Pieniny Limestone, especially due to white colour on weathered surfaces. The Kňažia Mb., however, differs by aleuritic texture (Figs. 2A and 3F) and lower degree of lithification (disintegration even after a light hammer strike) and typical splitting into elongated or spindle sharp-edged chips (Fig. 2B, D and G). Also, the Jurassic Kozinec Limestone can be confused with the Kňažia Mb., due to grey colour and similar aleuritic texture.

Name: The name Kňažia Member/Beds (Slovak: "*vrstvy Kňažej, člen Kňažej*") is derived from the name of the Kňažia settlement, today part of Dolný Kubín town, where stratotype is located.

Rank: Member within the Púchov Fm.; and contains bodies of the Bradlo-type limestone (Figs. 1 and 7).

Type section: Lithostratigraphic unit occurs in different parts of the studied Orava sector of the PKB. The proposed stratotype is located at the forest road cut north of Kňažia between points P198 and P247 (N 49.242911°, E 19.317906°; Tab. 1, Fig. 1). Well accessible localities with white marly limestone is present in the unpaved road East of the Kňažia settlement (locality P192) and in the slope West of Široká (OFZ factory, locality P145).

Other exposures in this area are in the ridge east of the Jelšava settlement (locality P240). The auxiliary section is at the forest road cut at the Lučivný vrch Hill (840 m a.s.l.) north of the Podbiel village (localities P963 – P967). It should be noted, that the road cut between Jelšava and Kňažia exposes tectonically strongly imbricated section with higher abundance of sandstones and pink marlstones, representing otherwise infrequent lithological types. Smaller occurrences are in the wider area of the Trstená town, west of the cooperative farm (P1087) and at the locality Vrch lazov (locality P1101) and in the cut of the Oravica river (P1051 and P1055). The lithostratigraphic unit is documented also from the locality Riedky diel (P564) NW of the Dolný Kubín – Malý Bysterec municipality, in the Repiská Hill (P1373) and the area W of the Beňova Lehota village (P579).

Thickness and boundaries: The thickness is irregular, 50–150 m in the area of the Opálené Hill, 50–200 m in the area of the Lučivný vrch Hill, and approx. 65 m east of Trstená. Larger thickness is obviously a result of the tectonic repetition of the sedimentary sequence or folding.

The lithostratigraphic unit represents lower part of the Púchov Fm. It is mostly surrounded by the Upper Cretaceous "klippen cover" flysch of the Snežnica and Sromowce fms. The poor outcrop conditions do not allow adequate documentation of the nature of the contact. It may be a stratigraphic contact, where the Kňažia Mb. overlaps a slightly older flysch, as well as at least partly tectonic contact. It should be noted, that in a map scale and from the sedimentological point, the Kňažia Mb. represents antagonistic facies to the sandstone flysch of the Snežnica and Sromowce fms. and is younger.

The member is locally in a tectonic contact with older rocks of the Posidonia (Harcygrund) and Pieniny formations. It may be overlapped by the calcareous sandstone and conglomerate of the Jarmuta Fm.

Age: The white marly limestone is of the middle Campanian age based on a presence of planktonic foraminiferal assemblage with *Contusotruncana plummerae*, *Globotruncana arca*, *G. bulloides*, *G. lapparenti*, *G. linneiana*, *G. ventricosa*, *G. hilli*, *Globotruncanita elevata*, *G. insignis* and *G. stuartiformis* (see Tab. 2).

Depositional environment: Studied white marly limestone was deposited in a basinal pelagic environment without any significant coarse siliciclastic sediment input. Pelagic sediments are locally cut by channels and aprons of coarser-grained shallow water calciclastic detritus.

Fig. 2. A – Detail on fresh surface of white marly limestone (Opálené Hill, P138); B – Exposure of the stratotype of white marly limestone in the unpaved road N of Kňažia (between points P198 and P247); C – Cut below the power line with the debris of white marly limestone (P145); D – Detail on the calcarenite with intraclasts of white marly limestone (P145); E – calcarenite with angular intraclasts of white marly pelagic Kňažia Mb. limestone; F – Outcrop of the grey marly limestones W of Beňova Lehota (P579); G – Calcarenite with angular fragments of grey limestone (P579).

Fig. 3. The Kňažia Member. A – Detail on white marly limestone with characteristic medium-grained texture, Lučivný vrch Hill (P956); B – Debris of white marly limestone in the forest road cut NW of Lučivný vrch Hill (P963); C – Grey calcarenites W of Lučivný vrch Hill (P788); D – Exposure of the white limestone at the Lučivný vrch Hill (P966); E – Exposure of Kňažia Mb. in the cut of Oravica river (P1055); F – Detail on white marly limestone on the previous locality (P1055); G – Debris of white to grey marly limestone, cut of Zábiedovčík brook (P1101).

Bradlo-type limestone

Lithology: Grey thin- to thick-bedded biodetritic (allodapic) limestone or medium- to coarse-grained calcarenite to calcirudite (microbreccia). Usually massive, locally laminated or cross-bedded (Figs. 4 A–D). The carbonate grains are predominantly of the psammite fraction, rarely with rounded or angular clasts of the psephite fraction (carbonate conglomerates). Intraclasts of white limestone with planktonic foraminifera (Kňažia Mb.) up to 4 cm in diameter are frequent (Figs. 2D–E). Grey calcarenites are relatively resistant to erosion, therefore often form ridges and are better exposed than the finer-grained Kňažia Mb.

Carbonate as well as polymictic, rarely also exotic conglomerate bodies or interbeds may be present. The interbeds of the exotic conglomerates with clasts of granites and rhyolites 2–30 cm in diameter were observed at several localities near Kňažia, Hldočín Valley and cut of the Oravica river (P247; P978, P1067; P1653; Figs. 4F and 5F).

Rarely *Thalassinoides* burrows (Fig. 5C) and rudists are observed at the Hldočín Valley west of the Zemianska Dedina settlement (locality P978; Figs. 5D–E). At this locality also otherwise uncommon coalified plant detritus was present in the calcarenites. The rudist fauna from this locality was described by Kühn & Andrusov (1942) and Andrusov (1959).

According to microfacies study, the limestone represents packstone to grainstone (biomicrite to biomicrosparite) with minor or almost no siliciclastic admixture. It contains small-sized planktonic foraminifera with globular chambers, larger representatives of the family *Globotruncanidae* and large benthic foraminifera belonging mostly to the genus *Preasiderolites*. In addition, the calcarenite commonly contained fragments of echinoderms, inoceramus shells, rudists, bryozoans and coralline algae. Frequent clasts of dolomites, micritic limestones with *Calpionella alpina* or radiolarians and silicified clasts are present. Additionally, also sandstone and mafic volcanic clasts were scarcely observed.

Clastic monocrystalline quartz is present only locally. Usually only small, angular to poorly-rounded grains with a diameter below about 0.2–0.25 mm and undulatory extinguishing are present.

Name: Term Bradlo-type limestone (Slovak: *vápence bradlianskeho typu*; originally defined as Široké bradlo Limestone Member – part of the Bradlo Formation of the Brezová Group; Samuel et al., 1980; now redefined as the Bradlo Formation by Potfaj et al., 2014; Teťák et al., 2015) is proposed, due to identical lithological content and stratigraphic age. The studied limestone was formerly described as "*organodetritic limestone of Gbeľany Formation*" (Marschalko et al., 1979; Gross et al., 1993). It should be noted, that Salaj & Köhler (2001) referred to the biodetritic limestones as the so-called "*Lučivný vrch facies*" (Slovak: "*vývoj Lučivného vrchu*") based on the occurrence at the Lučivný vrch Hill north of the Podbiel village. However, we do not recommend using this name anymore, because of the possibility of confusion with the Maiolica facies Lučivná Formation (see Polák & Bujnovský, 1979).

Rank: Informal lithostratigraphic unit within the Púchov Formation. According to present knowledge, the lithostratigraphic unit usually occurs together with and within the newly defined Kňažia Mb. (Figs. 1 and 7).

Type section: The type section within the studied sector of the PKB is located in the ridge of the Opálené Hill (locality P138, between the Široká and Jelšava settlements). The auxiliary section is located in the northern and southern slopes of the Lučivný vrch Hill (localities P963 – P967, north of Podbiel). Particular attention should be paid to the occurrence of the biodetritic limestones with rudist and exotic conglomerates in the Hldočín Valley (location P978, west of the Zemianska Dedina settlement).

Thickness and boundaries: Biodetritic limestones form 5–30 m thick lenticular bodies within the white marly limestones of the Kňažia Mb. The Bradlo-type limestone occurs in the lower, middle, and upper parts of the Kňažia Mb. In the area of the Hldočín Valley (locality P978) the biodetritic limestones with rudists and exotic conglomerates are up to 50 m thick and cut into the flysch of the Snežnica and Sromowce fms. Similar situation is in the area north of Dolný Kubín (P1653). The occurrence in the Hldočín Valley represents the base of the Bradlo-type limestone.

Age: Middle-upper Campanian, based on planktonic foraminifera (this study, see Biostratigraphy chapter below), and larger benthic foraminifera *Praesiderolites douvillei*, *Praesiderolites dordoniensis*, *Pseudosiderolites vidali*, with accompanying assemblage of other larger foraminifera *Orbitoides* sp., *Lepidorbitoides* sp., *Goupillaudina* sp. *Helicorbitoides* sp. and *Dicyclina* sp. (Salaj & Köhler, 2001). The upper Santonian–Campanian age was determined according the rudist macrofauna from the calcarenite body in Hldočín valley (Kühn & Andrusov, 1942). Despite the samples from this locality are devoid of planktonic foraminifera and age indicative larger benthic foraminifera; an older age of this body can be assumed, also based on the fact that its position can be interpreted as a channel cut into the uppermost part of the Snežnica and Sromowce fms.

Depositional environment: Studied calciclastic limestone is interpreted as allodapic slope aprons and channel fill composed of shallow water carbonate debris within the white marly limestones of the Kňažia Mb. or cut into the older Snežnica and Sromowce fms. The presence of white marly limestone intraclasts within the biodetritic

Fig. 4. Bradlo-type limestone. A – Detail on fresh surface of grey calcarenite, Opálené Hill (P138); B – Laminated calcarenite, Opálené Hill, W of Široká; C – Weathering of thick bedded calcarenites, Opálené Hill (P138); D – Cross-bedded calcarenites, N of Lučivný vrch Hill (P967); E – Fresh surface of coarse grained calcarenite to breccia N of Lučivný vrch Hill; F – Admixture of exotic conglomerates with rhyolite clasts, cut of Oravica river (P1067

Fig. 5. Calcarenites in the Hldočín section. A – Detail on calcarenite with cross-section of inoceramus shell; B – Calcarenite with coalified plant detritus (P978); C – *Thalassinoides* burrows (P978); D – Calcarenite with rudists (P978); E – Biodetritic limestone with fragmented shell detritus; F – Exposure of contact of rudist-bearing calcarenites above the exotic conglomerate bed (P978).

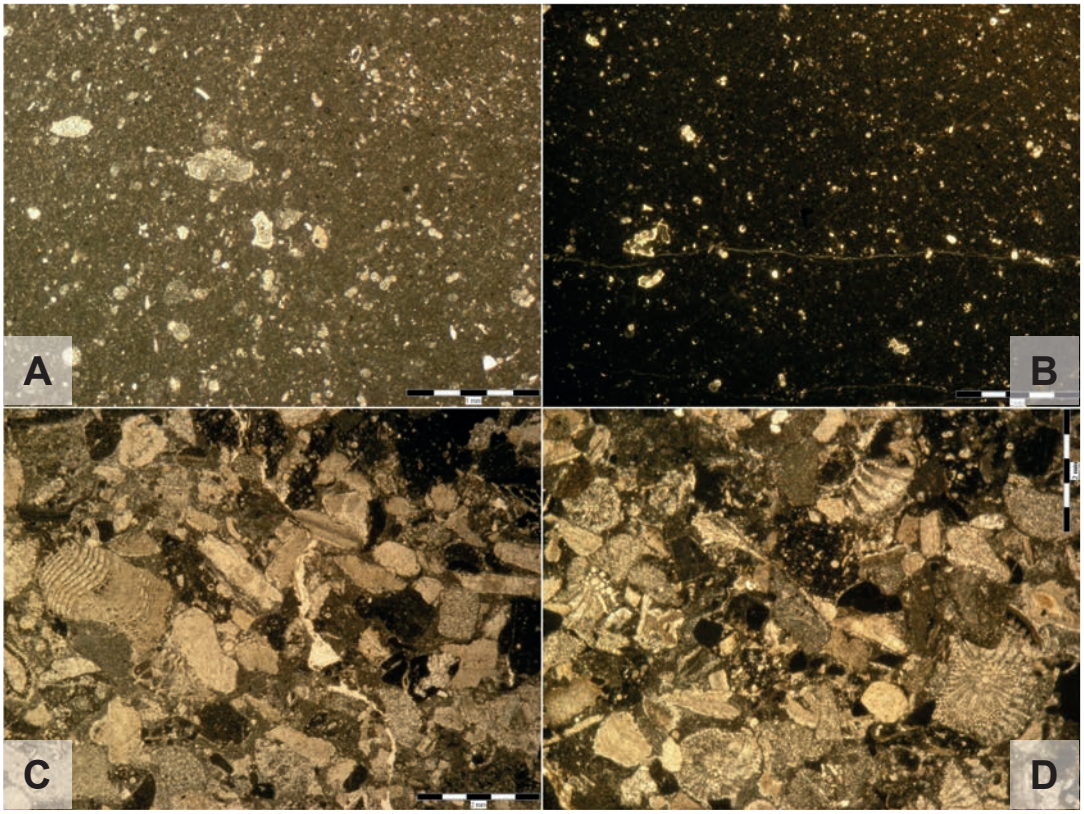


Fig. 6. Microfacies of the studied rocks. A–B – Kňažia Member; A – Wackstone with planktonic foraminifera (P135); B – Wackstone with planktonic foraminifera (P138H); C–D – Bradlo-type limestone: C – Grainstone with dominant rudist fragments and other biodetritus (P138C); D – Grainstone with fragments of larger benthic foraminifera (*Praesiderolites* spp.) (P138E).

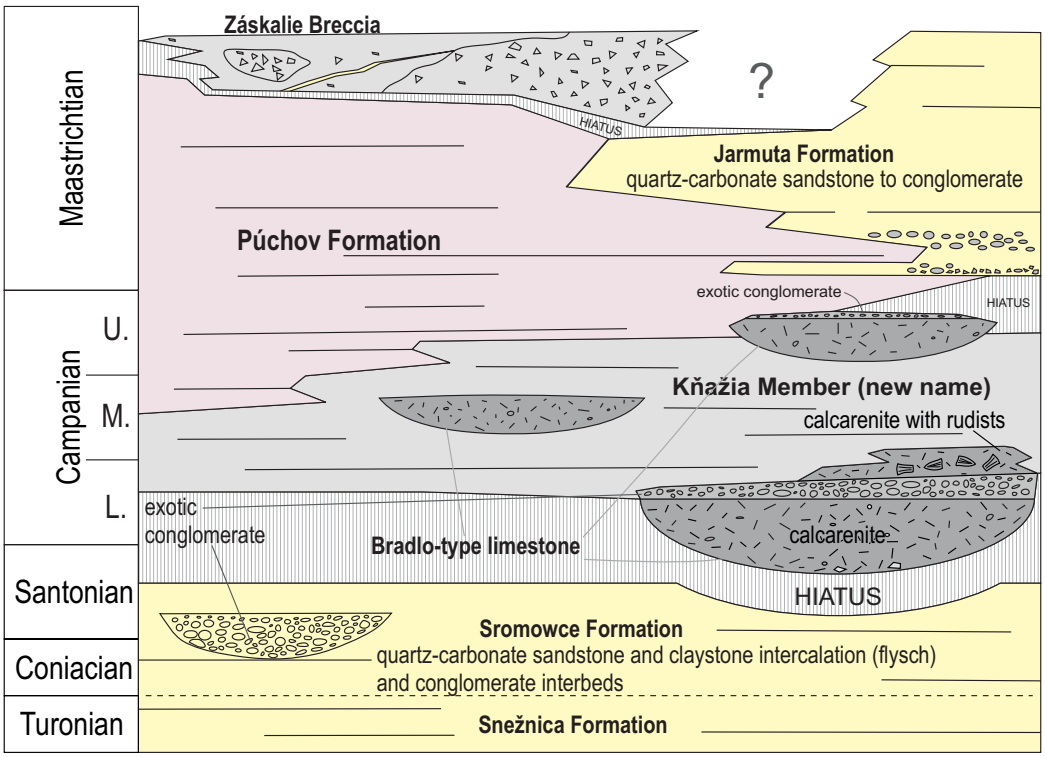


Fig. 7. Proposed sedimentary scheme of the Púchov Formation and its relationship with the Kňažia Member and the Bradlo-type limestone.

limestone points to erosion and redeposition of unconsolidated surrounding slope and basinal deposits.

Biostratigraphy

The marly limestones of the Kňažia Mb. are rich in planktonic foraminifera, while planktonic foraminifera from calcarenites with *Praesiderolites* spp. and beds of distal calciturbidites are mostly accessory. The microfacies of the Kňažia Mb. is represented by wackestones-packstones (planktonic foraminiferal biomicrites; Tab. 2) Microfacies of the Bradlo Mb. is represented by (fine-grained biodetritic-larger benthic foraminiferal biomicrites/biomicrosparites with lithoclasts). The most abundant in the samples are smaller planktonic foraminifera with globular chambers of *Muricohedbergella* spp. and scarce *Rugoglobigerina* spp. (trochospiral morphotypes). Planispiral morphotypes represented by *Laeviella* cf. *bollii* (Pessagno) are scarce (Fig. 8D–E). Relatively common are smaller biserial types of *Heterohelix* spp. (Fig. 8B). The globotruncanids are occasional to abundant, represented by diverse assemblage including *Globotruncana arca* (Cushman), *Globotruncana bulloides* Vogler, *Globotruncana falsostuarti* Sigal, *Globotruncana hilli* Pessagno, *Globotruncana lapparenti* Brotzen, *Globotruncana linneiana* (d'Orbigny), *Globotruncana orientalis* El Naggar, *Globotruncana ventricosa* (White) (Fig. 9), rare *Contusotruncana plummerae* (Gandolfi) (Fig. 9L), occasional *Globotruncanita elevata* (Brotzen), *Globotruncanita insignis* (Gandolfi) and *Globotruncanita stuartiformis* (Dalbiez) (Fig. 8).

The composition of the planktonic foraminiferal assemblage from the marly limestones and fine-grained varieties of biodetritic limestones points to the middle Campanian age. The FO *G. ventricosa* is traditionally determined between the FO of *G. elevata* and FO *Rd. calcarata* by various authors (Robaszinski et al., 1984; Premoli Silva & Verga, 2004; Petrizzo et al., 2011). The value of *G. ventricosa* as a global biostratigraphic marker species is however questioned (Falzoni et al., 2011; Coccioni & Premoli Silva, 2015). Cushman (1927) defined the co-occurrence of *C. plummerae* and *G. elevata* and absence of *Rd. calcarata* as the *C. plummerae* Zone. Axial sections of *C. plummerae* are rare in the sample material however the presence of *G. insignis* might refine the age determination. The FO of *G. insignis* is determined between the FO of *C. plummerae* and the FO of *Rd. calcarata* (Robaszinski et al., 1984; Premoli Silva & Verga, 2004; Falzoni & Petrizzo, 2011).

In the Bradlo-type biodetritic limestone frequent *Praesiderolites* spp. are present. Salaj & Köhler (2001) determined two species *P. douvillei* and *P. dordoniensis*. Range of the species *P. douvillei* is known from the middle-upper Campanian (Velić, 2007; Vicedo & Robles Salcedo, 2022).

Discussion

Despite relatively common occurrence of the Upper Cretaceous Púchov Fm. and its equivalents in the PKB and adjacent tectonic units, it has not been subject of detailed sedimentological and biostratigraphical research. Most of the knowledge is limited to basic mapping works, biostratigraphic and only general stratigraphic knowledge (e.g., Kantorová & Andrusov, 1958; Salaj & Began, 1963; Birkenmajer, 1977; Mello et al., 2011). Given that equivalents of the Púchov Fm. occur in several lithotectonic units and have many local names (Krováriky Fm., Kysuca Beds, Lalinok Fm., Gbeľany Fm. etc.), it may be more appropriate to redefine the Púchov Fm. as a lithostratigraphic unit at the group rank in the future.

While the lithological composition and position of the Kňažia Mb. (new name) can be considered more or less unique, the Santonian–Campanian biodetritic limestones are correlated with the Bradlo Formation (Samuel et al., 1980; Potfaj et al., 2014; Teťák et al., 2015) and denoted here as the Bradlo-type limestone. It should be noted that the biodetritic limestones with the exotic conglomerate interbeds and rudists documented at the Hldočín Valley west of the Zemianska Dedina settlement, are partly equivalent of the Hradisko Formation (Kysela et al., 1982) or Bezdedov Limestone of the Ihrište Formation (Salaj, 1990). However, a correlation of these formations requires a further detailed study and is beyond the scope of this paper.

One of the remaining open questions is the nature of the contact of the Kňažia Mb. with the flysch of the Snežnica and Sromowce fms. There are several places where the Kňažia Mb. is interbedded within the Snežnica and Sromowce fms. (e.g., NE of the Kňažia settlement; E and W of the Jelšava settlement). Considering the Coniacian–Santonian age of the Snežnica and Sromowce fms., the expected interfingering is not possible. A similar problem is posed by the position of the klippen of calcarenites of the Bradlo-type limestone in the Hldočín Valley (P978), or N of Dolný Kubín (P1653), situated within the Snežnica and Sromowce fms. At Hldočín locality, upper Santonian–Campanian age is documented (Kühn & Andrusov, 1942). However, one cannot agree with the interpretation that the rudists are in a growth position. The rudists are clearly redeposited (Fig. 5F). Based on the structural position and documented age, the Hldočín Valley exposure is interpreted as the base of the Bradlo-type limestone.

The geological mapping of the studied lithostratigraphic units suggests affiliation with the Orava/Podbiel or Kysuca succession. However, we do not see the complete stratigraphic sequences in the tectonic mélange of the Orava sector of PKB, and therefore tectonic classification to the Pieniny Unit is considered tentative.

Tab. 2

Planktonic foraminifera and *Praesiderolites* spp. occurrence in the studied samples

Locality	**Tvr.**	**Luč.v.**		**Podb.**	**H.L.**	**Kňažia - Široká**												**Luč.v.W**		**J-K.**
Microfacies	**W**	**W**	**R (M)**	**G (M)**	**W**	**W**	**W**	**W**	**P**	**P**	**R**	**R**	**R**	**R**	**R**	**W**	**P**	**G**	**R (M)**	**R (G)**
Species/samples	OP1011OM	OP966aOM	OP967OM	OP819OM	OP529OM	OP149OM	OP138H	OP138AO	OP138A	OP138bOM	OP138cOM	OP138dOM	OP138eOM	OP138fOM	OP138gOM	OP135OM	OP145OM	OP792OM	OP789OM	OP240OM
Heterohelix spp.	+	+	+	+	+	+	+	+	+							+	+	+	+	+
Muricohedbergella spp.	+	+	+	+	+	+	+	+	+		+				+	+	+	+	+	+
Rugoglobigerina spp.		+							+							+				+
Laeviella cf.*bollii*		+			+															
Contusotruncana plummerae				+	?													+		+
Globotruncana arca	+	+	+	+	+	+	+	+	+	+	+				+	+	+	+	+	+
Globotruncana bulloides	+	+		+	+	+	+		+	?						+				+
Globotruncana lapparenti	+	+	+	+	+	+	+	+	+							+	+			
Globotruncana linneiana	+	+		+	+	+	+		+							+		+		
Globotruncana hilli	+				+				+									+		+
Globotruncana orientalis		+							+											
Globotruncana ventricosa	+	+		+	+	+	+	+	+							+			+	+
Globotruncanita elevata		+				+	?		+							+	+			
Globotruncanita falsostuarti			+	?	+	+			+											+
Globotruncanita insignis		+	+						?							+				
Praesiderolites spp.			+						+	+	+	+	+	+	+		+		+	+

W – Wackestones (planktonic foraminiferal biomicrites). P – Packestones (fine-grained crinoidal-biodetritic biomicrites with admixture of planktonic foraminifera). G – Grainstones (M – microbreccia). R – Rudstones. Localities: Tvr. – Tvrdošín, Luč.v. – Lučivný vrch Hill, Podb. – Podbiel, H.L. – Horná Lehota, Luč.v.W. – Lučivný vrch, western side. J-K. – Jelšava-Kňažia.

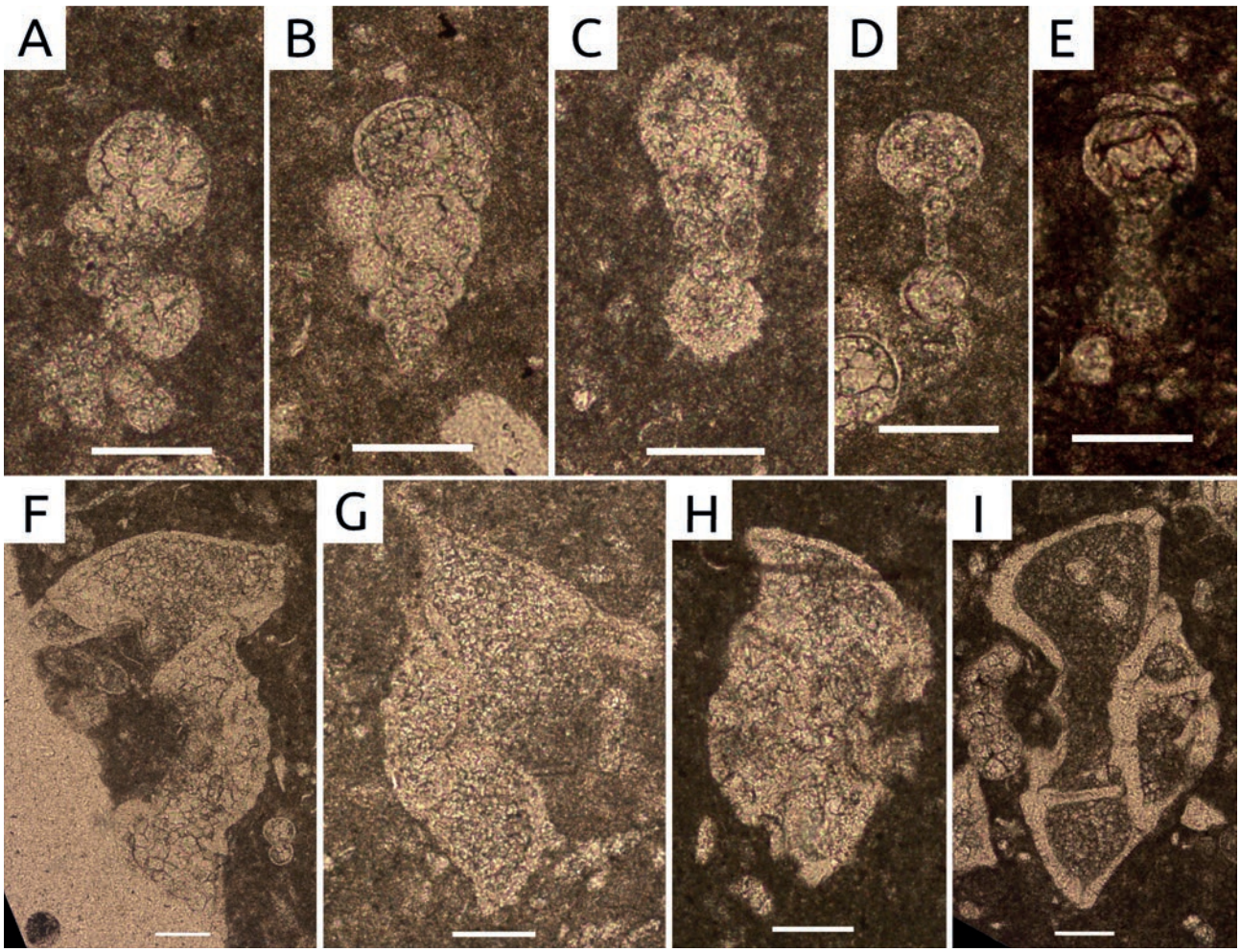


Fig. 8. A – *Muricohedbergella* cf. *monmouthensis* (Olsson), P966a; B – *Heterohelix* sp. P966a; C – *Rugoglobigerina* sp., P135; D–E – *Laeviella* cf. *bollii* (Pessagno), D – P966, E – P529; F–G – *Globotruncanita elevata* (Brotzen), F – P966a; G – P135; H – *Globotruncanita insignis* (Gandolfi), P135; I – *Globotruncanita stuartiformis* (Dalbiez), P149. Scale bar 100 μm.

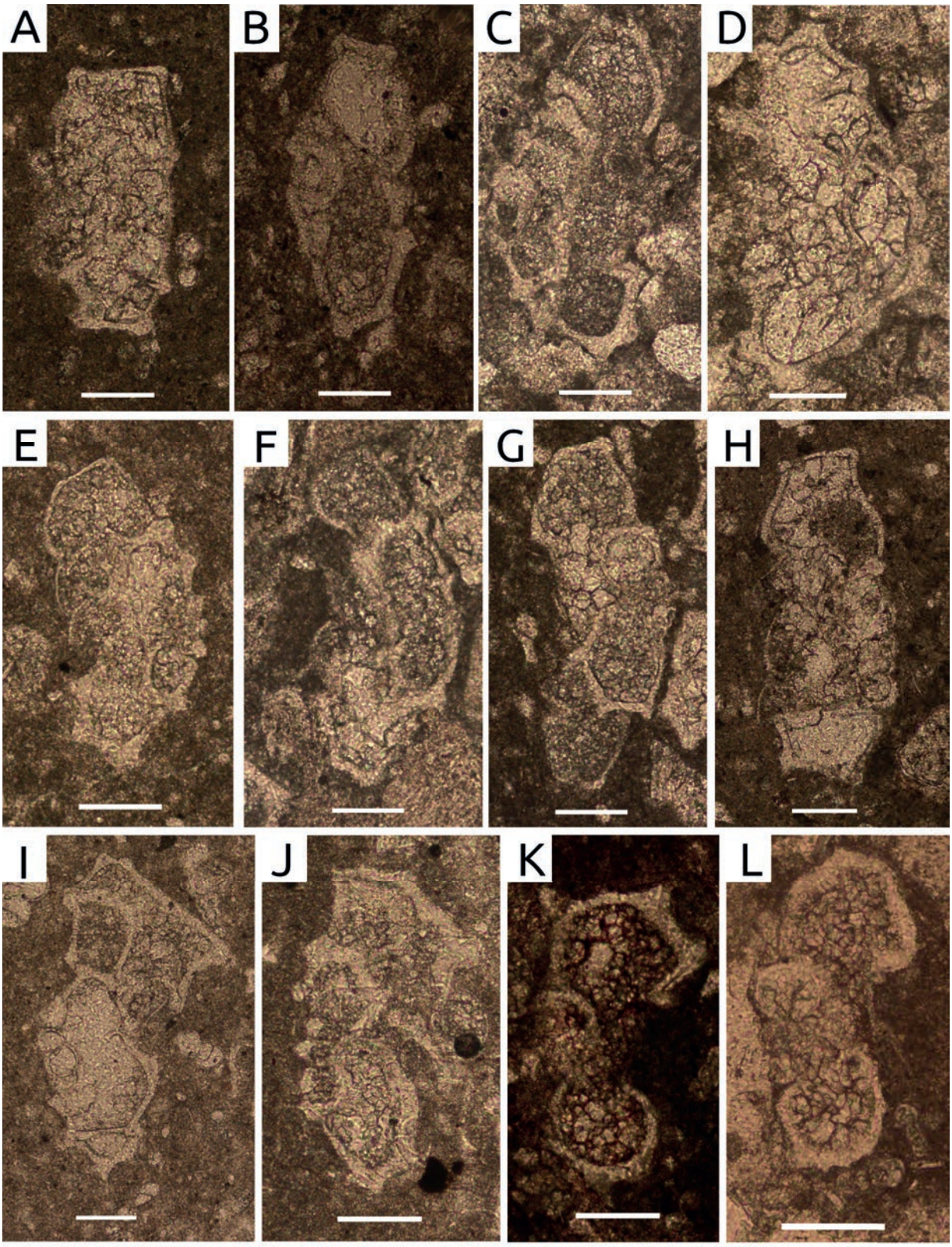


Fig. 9. A – *Globotruncana linneiana* (d'Orbigny), P1101; B – *Globotruncana lapparenti* Brotzen, P138a. C–D – *Globotruncana arca* (Cushman); C – P138a; D – P792; E–F – *Globotruncana orientalis* El Naggar; E – P966a; F – P138a; G–H – *Globotruncana bulloides* Vogler; G – P149; H – P1101; I–J – *Globotruncana ventricosa* (White); I – P1101; J – P138h; K – *Globotruncana hilli* Pessagno, P529; L – *Contusotruncana plummerae* (Gandolfi), P819.

Conclusions

The results of geological mapping, microfacies and biostratigraphic study in the area of Orava sector of the Pieniny Klippen Belt allow to distinguish new lithostratigraphic unit named the Kňažia Mb. of the Púchov Fm. The Kňažia Mb. is represented by white or grey marly limestone with planktonic foraminifera of middle Campanian age. Thickness varies between 50–200 m. The marly limestone locally contains interbeds of grey calcarenite or biodetritic limestone and conglomerate correlated with the Bradlo-type limestone. The calcarenites are also cut into the underlying Snežnica and Sromowce fms. The Bradlo-type limestone contains apart of planktonic and benthic foraminifera also rudist macrofauna which points to upper Santonian–Campanian age. The overall thickness of the member does not exceed 50 m. The studied lithostratigraphic units are tentatively assigned in the Orava/Podbiel resp. Kysuca succession of the Pieniny Unit.

Acknowledgements

The study was financially supported by the Ministry of Environment of Slovak Republic project no. 02 20 *Geological map of the Oravská Magura Mts.* at scale 1:50,000. Š. Józsa wishes to thank the projects APVV-22-0523 and VEGA 2/0106/23 for financial support. The authors thank reviewers Prof. RNDr. Roman Aubrecht, Dr., and RNDr. Miroslav Bubík, CSc., for their constructive comments and Prof. RNDr. Dušan Plašienka, DrSc., for oversight as handling editor.

References

Andrusov, D., 1931a: Geologická mapa útesového pásma v údolí Oravy 1 : 25 000. Díl východní. In: Matějka, A. & Andrusov, D. (eds.): Guide des excursions dans les Carpathes occidentales. *Praha, Státní geologický ústav Československé republiky*, 397 pp.

Andrusov, D., 1931b: Geologická mapa útesového pásma v údolí Oravy 1 : 25 000. Díl západní. In: Matějka, A. & Andrusov, D. (eds.): Guide des excursions dans les Carpathes occidentales. *Praha, Státní geologický ústav Československé republiky*, 397 pp.

Andrusov, D., 1938: Geologický výzkum vnitřního bradlového pásma v Západních Karpatech, část III.: Tektonika. *Rozpr. St. geol. Úst. Čs. republiky*, IX, 1 – 136 (in Czech, French summary).

Andrusov, D., 1959: Geológia Československých Karpát, Zv. II. *Bratislava, Veda, Vydavateľstvo Slovenskej akadémie vied*, 375 pp. (in Slovak).

Andrusov, D. & Scheibner, E., 1960: Prehľad súčasného stavu poznatkov o geológii bradlového pásma medzi Vlárou a Tvrdošínom. *Geologický sborník*, 11, 2, 239–279 (in Slovak, English summary).

Bezák, V. (ed.), Elečko, M., Fordinál, K., Ivanička, J., Kaličiak, M., Konečný, V., Kováčik, M. (Košice), Maglay, J., Mello, J., Nagy, A., Polák, M., Potfaj, M., Biely, A., Bóna, J., Broska, I., Buček, S., Filo, I., Gazdačko, Ľ., Grecula, P., Gross, P., Havrila, M., Hók, J., Hraško, Ľ., Jacko, S. Jr., Jacko, S. Sr., Janočko, J., Kobulský, J., Kohút, M., Kováčik, M. (Bratislava), Lexa, J., Madarás, J., Németh, Z., Olšavský, M., Plašienka, D., Pristaš, J., Rakús, M., Salaj, J., Siman, P., Šimon, L., Teťák, F., Vass, D., Vozár, J., Vozárová, A. & Žec, B., 2008: Prehľadná geologická mapa Slovenskej republiky 1 : 200 000. *Bratislava, Ministerstvo životného prostredia SR, Štátny geologický ústav Dionýza Štúra.*

Bezák, V. (ed.), Elečko, M., Fordinál, K., Ivanička, J., Kaličiak, M., Konečný, V., Maglay, J., Mello, J., Nagy, A., Polák, M., Potfaj, M., Šimon, L., Biely, A., Broska, I., Buček, S., Filo, I., Grecula, P., Hraško, Ľ., Jacko, S., Kobulský, J., Kohút, M., Kováčik, M., Lexa, J., Olšavský, M., Plašienka, D., Pristaš, J., Teťák, F., Vass, D. & Vozárová, A., 2009: Vysvetlivky k Prehľadnej geologickej mape Slovenskej republiky 1 : 200 000. *Bratislava, Štátny geologický ústav Dionýza Štúra*, 534 pp. (in Slovak, English summary).

Birkenmajer, K., 1977: Jurassic and Cretaceous lithostratigraphic units of the Pieniny Klippen Belt, Carpathians, Poland. *Studia geologica Polonica*, 45, 1–158.

Birkenmajer, K., 1986: Stages of structural evolution of the Pieniny Klippen Belt, Carpathians. *Studia geologica Polonica*, 88, 7–32.

Borza, V., Ondrejíčková, A. & Halásová, E., 1993: Litostratigrafia strednej jury – spodnej kriedy Podbielskeho bradla (Orava). *Manuscript. Bratislava, Archive of St. Geol. Inst. of D. Štúr* (arch. no. 78633), 34 pp. (in Slovak).

Caron, M., 1985: Cretaceous planktic foraminifera. In: Bolli, H. M., Saunders, J. B. & Perch-Nielsen, K. (eds.): Plankton Stratigraphy, Volume 1: Planktic Foraminifera, Calcareous Nannofossils and Calpionellids. *Cambridge, Cambridge University Press*, 17–86.

Cushman, J. A., 1927: An outline for the re-classification of the foraminifera: Contributions from the Cushman Laboratory for Foraminiferal Research, 3. *Sharon*, 105 pp.

Coccioni, R. & Premoli-Silva, I., 2015: Revised Upper Albian-Maastrichtian planktonic foraminiferal biostratigraphy and magnetostratigraphy of the classical Tethyan Gubbio section (Italy). *Newsletter Stratigraphy*, 48, 1, 47–90. https://doi.org/10.1127/nos/2015/0055.

Falzoni, F. & Petrizzo, M. R., 2011: Taxonomic overview and evolutionary history of *Globotruncanita insignis* (Gandolfi, 1955). *Journal of foraminiferal research*, 41, 4, 371–383. https://doi.org/10.2113/gsjfr.41.4.371.

Flügel, E., 2010: Microfacies of Carbonate Rocks Analysis, Interpretation and Application. *Berlin, Springer*, 984 pp. https://doi.org/10.1007/978-3-642-03796-2.

Gross, P., Haško, J., Dovina, V., Halouzka, R. & Szalaiová, V., 1980: Vysvetlivky k listu Dolný Kubín 1 : 25 000. Čiastková záverečná správa za rok 1979. *Manuscript. Bratislava, Archive of St. Geol. Inst. of D. Štúr* (arch. no. 45327).

Gross, P., Haško, J. & Halouzka, R., 1984: Vysvetlivky ku geologickej mape 1 : 25 000, list 26 413 (Trstená 3). Čiastková

záverečná správa. Manuscript. *Bratislava, Archive of St. Geol. Inst. of D. Štúr* (arch. no. 57740), 86 pp. (in Slovak).

Gross, P., Köhler, E., Mello, J., Haško, J., Halouzka, R., Nagy, A., Kováč, P., Filo, I., Havrila, M., Maglay, J., Salaj, J., Franko, O., Zakovič, M., Pospíšil, L., Bystrická, H., Samuel, O. & Snopková, P., 1993: Geológia južnej a východnej Oravy. *Bratislava, Geologický ústav Dionýza Štúra*, 319 pp. (in Slovak, English summary).

Haško, J., 1978: Oravská séria – nová séria bradlového pásma Západných Karpát. *Geologické práce, Správy*, 70, 115–121 (in Slovak).

Haško, J. & Polák, M., 1978: Geologická mapa Kysuckých vrchov a Krivánskej Malej Fatry v mierke 1 : 50 000. *Bratislava, Geologický ústav Dionýza Štúra*.

Haško, J. & Polák, M., 1979: Vysvetlivky ku geologickej mape Kysuckých vrchov a Krivánskej Malej Fatry 1 : 50 000. *Bratislava, Geologický Ústav Dionýza Štúra*, 145 pp. (in Slovak).

Hu, X., Jansa, L., Wang, Ch., Sarti, M., Bak, K., Wagreich, M., Michalík, J. & Soták, J., 2006: Upper Cretaceous oceanic red beds (CORBs) in the Tethys: occurrences, lithofacies, age, and environments. *Cretaceous Research*, 26, 3 – 20. https://doi.org/10.1016/j.cretres.2004.11.011.

Jablonský, J. & Halásová, E., 1994: Resedimentation as a reflection of Laramian processes in the Pieniny Klippen Belt near Jelšava, Orava region, Western Carpathians. In: Michalík, J. & Reháková, D. (eds.): Abstract Book in the IGCP 362 Project Annual Meeting, Smolenice 1994, Konferencie, Sympóziá, Semináre. *Bratislava, Geologický ústav Dionýza Štúra*, 93–94.

Kantorová, V. & Andrusov, D., 1958: Mikrobiostratigrafický výskum strednej a vrchnej kriedy Považia a Oravy. *Geologický sborník*, 9, 2, 165–177 (in Slovak, French summary).

Kühn, O. & Andrusov, D., 1942: Stratigraphie und Palaogeographie der Rudisten. III. Rudistenfauna und Kreideentwicklung in den Westkarpathen. *Neues Jahrbuch Mineralogie Geologie Paläontologie Beitrag*, 86, 450–480 (in German).

Kysela, J., Marschalko, R. & Samuel, O., 1982: Litostratigrafická klasifikácia vrchnokriedových sedimentov manínskej jednotky. *Geologické práce, Správy*, 78, 134–167 (in Slovak, English summary).

Lexa, J., Bezák, V., Elečko, M., Mello, J., Polák, M., Potfaj, M. & Vozár, J. (eds.), 2000: Geological map of Western Carpathians and adjacent areas 1:500,000. Ministry of the Environment of Slovak Republic. *Bratislava, Geological Survey of Slovak Republic*.

Liščák, P., Pauditš, P., Bystrická, G., Teťák, F., Maglay, J., Dananaj, I., Ondrus, P., Mašlár, E., Mašlárová, I., Olšavský, M., Pelech, O., Vitovič, L., Leitmannová, K., Fraštia, M. & Papčo, J., 2022: Využitie DMR 5.0 z leteckého laserového skenovania pri riešení geologických úloh ŠGÚDŠ. *Geodetický a kartografický obzor*, 68, 110, 8, 149–159 (in Slovak, English summary).

Marschalko, R., 1986: Vývoj a geotektonický význam kriedového flyšu bradlového pásma. Bratislava, Veda, vydavateľstvo SAV, 137 pp. (in Slovak, English summary).

Marschalko, R. & Samuel, O., 1978: Poznámky k tektonickej príslušnosti flyšu v okolí Sedliackej Dubovej (bradlové pásmo). *Geologické práce, Správy*, 71, 111–122 (in Slovak, English summary).

Marschalko, R., Haško, J. & Samuel, O., 1979: Záskalské brekcie a proces vzniku olistostrómov (Bradlové pásmo na Dolnej Orave). *Geologické práce, Správy*, 73, 75–88 (in Slovak, English summary).

Matějka, A. & Hanzlíková, E., 1962: O paleogénu od obce Kňažia na Oravě. Zprávy o geologických výzkumech v roce 1961. *Praha, Ústřední ústav geologický*, 194–196 (in Czech).

Mello, J., Potfaj, M., Teťák, F., Havrila, M., Rakús, M., Buček, S., Filo, I., Nagy, A., Salaj, J., Maglay, J., Pristaš, J. & Fordinál, K., 2011: Vysvetlivky ku geologickej mape Stredného Považia 1 : 50 000. *Bratislava, Štátny geologický ústav Dionýza Štúra*, 378 pp. (in Slovak).

Michalík, J., Vass, D., Hudáčková, N., Kováčová, M., Lintnerová, O., Reháková, D., Soták, J., Schlögl, J., Aubrecht, R., Vozárová, A., Sliva, Ľ., Lexa, J., Konečný, V., Túnyi, I. & Potfaj, M., 2007: Stratigrafická príručka: slovenská stratigrafická terminológia, stratigrafická klasifikácia a postupy. *Bratislava, Veda, vydavateľstvo SAV*, 166 pp. (in Slovak).

Mišík, M., 1997: The Slovak part of the Pieniny Klippen Belt after the pioneering works of D. Andrusov. *Geologica Carpathica*, 48, 4, 209–220.

Petrizzo, M. R., Falzoni, F. & Premoli Silva, I., 2011: Identification of the base of the lower-to-middle Campanian Globotruncana ventricosa Zone: comments on reliability and global correlations. *Cretaceous Research*, 32, 387–405. https://doi.org/10.1016/j.cretres.2011.01.010.

Plašienka, D., 2018a: The Carpathian Klippen Belt and types of its klippen – An attempt at a genetic classification. *Mineralia Slovaca*, 50, 1, 1–24.

Plašienka, D., 2018b: Continuity and episodicity in the early Alpine tectonic evolution of the Western Carpathians: How large-scale processes are expressed by the orogenic architecture and rock record data. *Tectonics*, 37. https://doi.org/10.1029/2017TC004779.

Plašienka, D., Soták, J., Jamrichová, M., Halásová, E., Pivko, D., Józsa, Š., Madzin, J. & Mikuš, V., 2012: Structure and evolution of the Pieniny Klippen Belt demonstrated along a section between Jarabina and Litmanová villages in Eastern Slovakia. *Mineralia Slovaca*, 44, 1, 17–38.

Plašienka, D., Aubrecht, R., Bezák, V., Bielik, M., Broska, I., Bučová, J., Fekete, K., Gaži, P., Gedl, P., Golej, M., Halásová, E., Hók, J., Hrdlička, M., Jamrich, M., Józsa, Š., Klanica, R., Konečný, P., Kubiš, M., Madarás, J., Majcin, D., Marko, F., Molčan Matejová, M., Potočný, T., Schlögl, J., Soták, J., Suan, G., Šamajová, L., Šimonová, V., Teťák, F. & Vozár, J., 2021: Structure, composition and tectonic evolution of the Pieniny Klippen Belt – Central Western Carpathian contiguous zone (Kysuce and Orava regions, NW Slovakia). *Bratislava, Comenius University*, 148 pp.

Polák, M. & Bujnovský, A., 1979: The Lučivná formation (New designation of a formal lithostratigraphical unit of the lower Cretaceous of envelope groups in the West Carpathians). *Geologické práce, Správy*, 73, 61–70.

Potfaj, M., 1993: Postavenie bielokarpatskej jednotky v rámci flyšového pásma. *Geologické práce, Správy*, 98, 55–78 (in Slovak, English summary).

Potfaj, M., Haško, J., Gašpariková, V., Snopková, P. & Samuel, O., 1981: Vysvetlivky ku geologickej mape 1 : 25 000, list 26-411 (Trstená). Čiastková záverečná správa za rok 1977 – 1981. *Manuscript. Bratislava, Archive of St. Geol. Inst. of D. Štúr* (arch. no. 50488), 47 pp. (in Slovak).

Potfaj, M., Teťák, F. (eds.), Havrila, M., Filo, I., Pešková, I., Olšavský, M. & Vlačiky, M., 2014: Geological map of the Biele Karpaty Mts. (southern part) and the Myjavská pahorkatina Upland 1:50,000. *Bratislava, Štátny geologický ústav Dionýza Štúra.*

Premoli Silva, I. & Verga, D., 2004: Practical Manual of Cretaceous Planktonic Foraminifera. In: Verga, D. & Rettori, R. (eds.): International School on Planktonic Foraminifera, Universities of Perugia & Milano. *Perugia, Tipografia Pontefelcino*, 283 pp.

Robaszynski, F., Caron, M., Gonzales Donoso, J. M. & Wonders, A. A. H. (eds.), 1984: Atlas of Late Cretaceous Globotruncanids. *Revue de micropaléontologie*, 26, 3–4, 305 pp.

Salaj, J., 1990: Geologická stavba bradlovej a pribradlovej zóny stredného Považia a litologická klasifikácia kriedových sedimentov novovymedzených sekvencií. *Mineralia Slovaca*, 22, 2, 155–174 (in Slovak, English summary).

Salaj, J. & Began, A., 1963: Faciálne vývoje a mikrobiostratigrafia vrchnej kriedy bradlového pásma. *Geologické práce, Zprávy*, 30, 113 – 120 (in Slovak, German summary).

Salaj, J. & Köhler, E., 2001: Kampánsky rod *Praesiderolites* zo Západných Karpát. *Mineralia Slovaca*, 33, 351–360 (in Slovak, English summary).

Salvador, A. (ed.), 2013: International Stratigraphic Guide. *Boulder, Geological Society of America*, 214 pp. https://doi.org/10.1130/9780813774022.

Samuel, O., Salaj, J. & Began, A., 1980: Litostratigrafická charakteristika vrchnokriedových a paleogénnych sedimentov Myjavskej pahorkatiny. *Západné Karpaty, séria Geológia*, 6, 81 – 111 (in Slovak, English summary).

Stráník, Z., Bubík, M., Krejčí, O., Marschalko, R., Švábenická, L. & Vůjta, M., 1995: New litostratigraphy of the Hluk Development of the Bílé Karpaty unit. *Geologické práce, Správy*, 100, 57–69.

Stur, D., 1860: Bericht über die geologische Uebersichts--Aufnahme des Wassergebietes der Waag und Neutra. *Jb. K.-Kön. geol. Reichsanst.*, XI, 1, 17–151 (in German).

Teťák, F. & Potfaj, M. (eds.), Havrila, M., Filo, I., Pešková, I., Boorová, D., Žecová, K., Laurinc, D., Olšavský, M., Siráňová, Z., Buček, S., Kucharič, Ľ., Gluch, A., Šoltés, S., Pažická, A., Iglárová, Ľ., Liščák, P., Malík, P., Fordinál, K., Vlačiky, M. & Köhler, E., 2015: Vysvetlivky ku geologickej mape Bielych Karpát (južná časť) a Myjavskej pahorkatiny v mierke 1 : 50 000. *Bratislava, Štátny geologický ústav Dionýza Štúra*, 306 pp. (in Slovak).

Teťák, F., Pelech, O., Laurinc, D., Olšavský, M., Fekete, K., Vitovič, L., Maglay, J., Madzin, J., Demko, R. & Žecová, K., 2024: Geologická mapa Oravskej Magury v mierke 1 : 25 000 (západná časť). Čiastková záverečná správa geologickej úlohy. *Manuscript. Bratislava, Archive of St. Geol. Inst. of D. Štúr*, 153 pp. (in Slovak).

Teťák, F., Pelech, O., Laurinc, D., Olšavský, M., Fekete, K., Vitovič, L., Maglay, J., Demko, R. & Korábová, K., 2025: Geologická mapa Oravskej Magury v mierke 1 : 25 000 (východná časť). Čiastková záverečná správa geologickej úlohy. *Manuscript. Bratislava, Archive of St. Geol. Inst. of D. Štúr*, 150 pp. (in Slovak).

Velić, I., 2007: Stratigraphy and Palaeobiogeography of Mesozoic Benthic Foraminifera of the Karst Dinarides (SE Europe). *Geologia Croatica*, 60, 1, 1–113.

Vicedo, V. & Robles-Salcedo, R., 2022: Late Cretaceous larger rotaliid foraminifera from the westernmost Tethys. *Cretaceous Research*, 133, 105137, 1–31. https://doi.org/10.1016/j.cretres.2022.105137.

Santónsko-kampánske jemnozrnné a biodetritické fácie v púchovskom súvrství zdokumentované v oravskom úseku pieninského bradlového pásma

Táto práca predstavuje nové poznatky o púchovskom súvrství oravského úseku bradlového pásma. Termín púchovský slieň v bradlovom pásme na Strednom Považí zaviedol Stur (1860, s. 115) pôvodne na označenie červených a sivých slieňov vrchnokriedového veku. Pestré, najčastejšie červené sliene majú názvy definované pomerne nevhodne, len na základe svojho veku, geografického výskytu alebo príslušnosti k rôznym tektonickým jednotkám [v čorštynskej sukcesii chmielowské sliene (alb) a púchovské sliene s. s., resp. súvrstvie Jaworiek (cenoman – mástricht); kysucké (turón), lalinocké (cenoman) a gbelianske vrstvy, resp. súvrstvie (santón – mástricht) v kysuckej sukcesii atď.]. Súvrstvie tvoria ružové až tehlovo červené, zriedkavo aj zelené alebo sivé slieňovce až ílovité vápence alebo vápnité bridlice. Navetraná sutina slieňovcov až vápencov môže obsahovať vyvetrané globotrunkány pozorovateľné pod lupou. Zvetrané slieňovce niekedy tvoria červené eluviálne hliny. Pri geologickom mapovaní bolo možné od červených slieňovcov odlíšiť biele jemnozrnné až prachovité vápence s globotrunkánami a telesami kalkarenitov. Osobitosť týchto hornín, čiastočne odčleňovaných od púchovských vrstiev,

bola známa už skôr (Marschalko et al., 1979; Gross et al., 1993). Salaj a Köhler (2001) ich označovali ako tzv. vývoj Lučivného vrchu. Tento názov však ďalej neodporúčame používať pre možnosť zámeny s lučivnianskym súvrstvím.

Dominantnú časť novodefinovanej litostratigrafickej jednotky označenej ako **kňažiansky člen** alebo člen Kňažej (nový termín), resp. vrstvy Kňažej, tvoria tenkodoskovité až lavicovité biele až svetlosivé prachovité vápence s globotrunkánami. Litostratigrafická jednotka je súčasťou púchovského súvrstvia. Niekedy môžu byť podobné pieninskému súvrstviu, odlišujú sa však prachovitým vzhľadom, slabšou litifikáciou (rozpad aj po ľahšom údere kladiva) a ostrohranným až čriepkovitým rozpadom. Mikrofaciálne predstavujú kalové vápence (*wackstone* až *packstone*) s hojnými prierezmi planktonických dvojkýlových foraminifer. Miestami obsahujú prevrstvenia rôzne hrubých (2 – 4 m) doskovitých biodetritických vápencov – kalkarenitov. Vrstvy Kňažej sú pomenované podľa miestnej časti Dolného Kubína – Kňažia. Stratotyp sa nachádza v počve a záreze lesnej cesty severne od Kňažej medzi bodmi P198 a P247 (obr. 1, tab. 1). Druhým podobným výskytom je oblasť Lučivného vrchu (841 m n. m.) severne od Podbiela. Celkovo dosahujú hrúbku okolo 50 – 200 m. Vek globotrunkánových vápencov vrstiev Kňažej je na základe výskytu planktonických a bentických foraminifer stredný kampán.

Vápence bradlianskeho typu (alebo pôvodne vápence Širokého bradla redefinované v práci Teťák et al., 2015) predstavujú sivé kalkarenity, biodetritické vápence, brekcie a zlepence. Väčšinou sú masívne, miestami laminované alebo šikmo zvrstvené. Často obsahujú intraklasty bielych globotrunkánových vápencov vrstiev Kňažej. Tvoria výplne kanálov alebo vejáre plytkovodného detritu zarezané v rôznych častiach vrstiev Kňažej, resp. môžu erodovať najvyššiu časť podložného snežnicko-sromowského súvrstvia. Zriedkavo obsahujú aj medzivrstvy exotických zlepencov a vzácne v nich boli pozorované aj telesá s fragmentmi rudistových rifov. Termín zaužívaný v brezovskej skupine (Samuel et al., 1980; Potfaj et al., 2014) bol použitý kvôli zhodnému litologickému charakteru a zhodnej stratigrafickej pozícii uvedených kalkarenitov. Kalkarenity, resp. biodetritické vápence tvoria šošovkovité telesá hrubé 5 – 50 m. Hierarchicky sú súčasťou púchovského súvrstvia.

Stratotyp v rámci skúmaného úseku bradlového pásma sa nachádza v hrebeni Opáleného (lokalita P138 z. od Širokej, resp. Oravského Podzámku). Ďalšie profily sú v oblasti zárezu lesnej cesty v masíve Lučivného vrchu (lokality P963 – P967 severne od Podbiela). Osobitý význam má výskyt s asociáciou biodetritických vápencov s rudistami a exotikami v doline Hldočín (lokalita P978 z. od Zemianskej Dediny). Vek vápencov bradlianskeho typu bol doložený na základe mikrofauny planktonických a bentických foraminifer a makrofauny rudistov ako vrchný santón – vrchný kampán (Salaj a Köhler, 2001; Kühn a Andrusov, 1942).

Doručené / Recieved: 6. 6. 2025
Prijaté na publikovanie / Accepted: 1. 9. 2025