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Fossil and Subfossil Findings of Brown Bears from selected Localities in Slovakia

MARTIN SABOL

Department of Geology and Palaeontology, Faculty of Natural Sciences, Comenius University, Mlynská dolina, 842 15 Bratislava, Slovakia.

*Abstract.*The fossil remains of bears from the Late Pleistocene are very frequently found in the caves of the Western Carpathians. Occasionally, besides of the fossil remains of cave bears the remains of representatives of brown bears are also found in Slovak karst sediments dated from the Late Pleistocene Period to the start of the Holocene Period. Some of them belong to the taxa *Ursus arctos priscus* GOLDFUSS, 1822 (from the Last Glacial) and *Ursus arctos arctos* LINNÉ, 1758 (especially from the Holocene).

This paper gives a more detailed description of metric and morphologic characteristics of brown bear fossil and subfossil remains (especially teeth and skulls) from six Slovak karst localities: the Lisková Cave, the Lukáč Abyss, the Psie diery Cave, the Šípová Cave, the Važec Cave and the Vyvieranie Cave.

Key words: brown bears, metric and morphologic analysis, Last Glacial, Holocene, Slovak caves

Introduction

The fossil remains of bears from the Late Pleistocene are very frequently found in the caves of the Western Carpathians. The greatest number of these bear remains belongs to the species *Ursus spelaeus* ROSENMÜLLER & HEINRICH, 1794. Occasionally, the remains of representatives from the arctoid branch of the ursid phylogeny are also found in Slovak cave sediments dating from the Late Pleistocene Period to the start of the Holocene Period. These findings belong to the taxa *Ursus taubachensis* (RODE, 1931) (especially from the Eem Interglacial), *Ursus arctos priscus* GOLDFUSS, 1822 (from the Last Glacial) and *Ursus arctos arctos* LINNÉ, 1758, which has been present in our territory from the start of the Holocene or by the end of the Last Glacial Period.

This article gives a more detailed description of metric and morphologic characteristics of brown bear fossil and subfossil remains (especially teeth and skulls) from six Slovak karst locations: the Lisková Cave, the Lukáč Abyss, the Psie diery Cave, the Šípová Cave, the Važec Cave, and the Vyvieranie Cave.

Localities

The Lisková Cave (Fig. 1).

The cave is situated in the Lisková quarry in the Liptov depression near village of Lisková in the Ružomberok district. The cave opening, today filled is situated at 535 m above sea level. It is a small cave, only 40-m long.

The Lukáč Abyss (Fig. 1).

The Lukáč Abyss, also known as Lukáč Cave, is a small karst formation, situated in the Volovské vrchy Mountains, at Kojšovská hoľa hill near village of Kojšovo in the Gelnica district. This 33-m deep chasm is situated at 725 m above sea level.

The Psie diery Cave (the Dog's Holes Cave) (Fig. 1).

The Psie diery Cave belongs to the 21 000-m long Stratená cave system in the Slovenský raj Mountains. This is the most extensive cave system in Slovakia. The opening of this inactive through-cave is situated above an unnamed creek in the Tiesniny at Duča hill. It is a 194-m deep cave and is formed of the tectonic-broken Middle Triassic limestone. The Psie diery Cave was discovered by V. Košel and J. Volek in 1972 (Dub et al., 1977 – 1982).

The Šípová Cave (the Arrow Cave) (Fig. 1).

The Šípová Cave is situated under Dubná skala hill in the Strážovské vrchy Mountains near the village of Čierna Lehota. The osteological remains of brown bear were found here.

The Važec Cave (Fig. 1).

The Važec Cave, significant with its dripstone decoration, is situated on the south-western border of Važec village in the Liptovský Mikuláš district, in the Liptov depression, at 784 m above sea level. During the Pleistocene the cave was formed by the fluvial and chemical erosion of the Biely Váh River on the grey-blue Middle Triassic Guttenstein limestone that have been strongly affected by tectonic movement. These limestone alternate with the lighter dolomite. A quantity of cave bear bones have accumulated among the underground river gravel that have filled the cave, in some places as high as the

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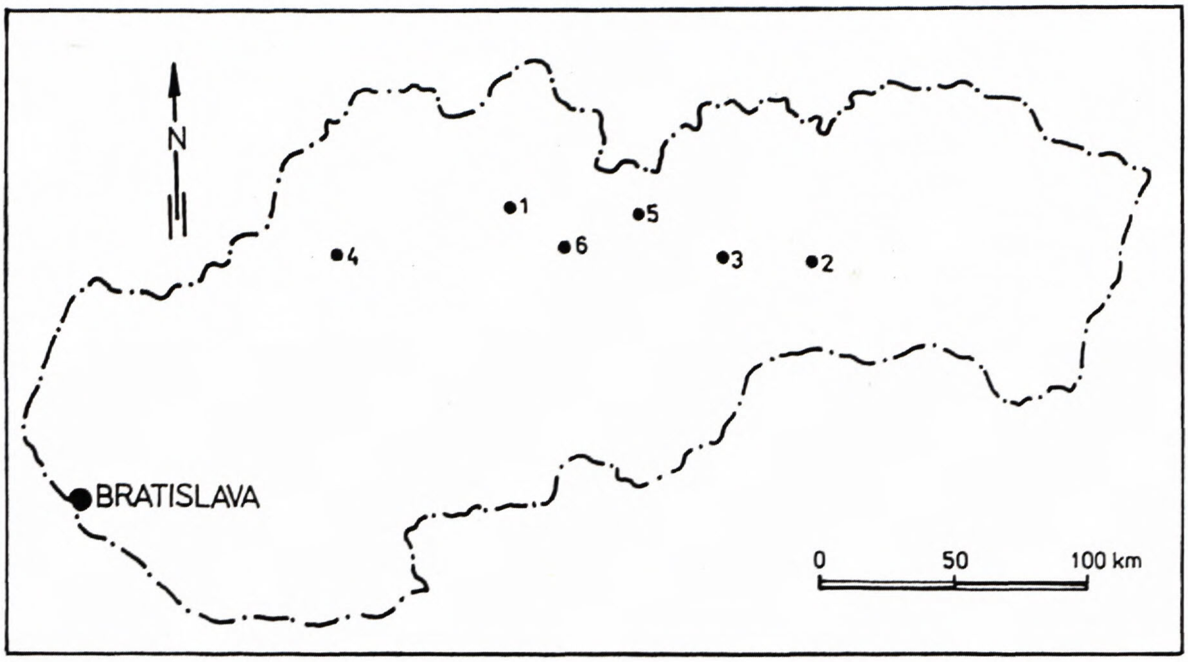

Fig. 1. Location of the individual localities
1– Lisková Cave, 2 – Lukáč Abyss, 3 – Psie diery Cave, 4 – Šípová Cave, 5 – Važec Cave, 6 – Vyvieranie Cave.

ceiling. This 400 meter long cave is an inactive through-cave, which has collapsed. A student, Ondrej A. Húska,discovered the Važec Cave 8th July 1922, and in 1968 the cave was established as a protected site (Dub et al., 1977 - 1982; Kučera et al., 1981).

The Vyvieranie Cave (the Cave of Springing) (Fig. 1).

The Vyvieranie Cave is situated south-west from the Okno Cave in the Demänová valley. Its opening is 719 m above sea level. This through-cave is 1 538 m long and is a ground water discharge of Demänovka creek (Kučera et al., 1981).

Material and Methods

The studied material is for the most part deposited in the Slovak Museum of Nature Protection and Speleology in Liptovský Mikuláš. An exception being the fossil material taken from sediments of the Lisková Cave, which are deposited in the Liptov Museum in Ružomberok. Unfortunately, the circumstances regarding their discoveries are not known; we only know that these fossil cave bear remains came from older excavations in these caves or they were found on the surface in caves. Altogether 38 teeth, 7 mandibles and 5 skulls have been studied metrically and morphologically. The following works were used during the study of these fossil remains: Musil (1962, 1964, 1965, 1969, 1991), Erdbring (1953), Feriancová-Masárová and Hanák (1965), Sabol (1998, *in press*) and Sládek (1991). From the metric point of view, the material was compared with findings from other caves and sites, especially in Slovakia and Moravia.

Systematic Part

System

Class MAMMALIA LINNAEUS, 1758
Order CARNIVORA BOWDICH, 1821
Suborder CANIFORMIA KRETZOI, 1945
Infraorder ARCTOIDEA FLOWER, 1869
Order-group taxon ARCTOMORPHA WOLSAN, 1993
Superfamily URSOIDEA GRAY, 1825
Family URSIDAE GRAY, 1825
Subfamily URSINAE VIRET, 1955
Genus URSUS LINNAEUS, 1758

Species *Ursus arctos* LINNAEUS, 1758

Type locality: Sweden
Geological age: Middle Pleistocene – Recent
Distribution: Europe (Middle Pleistocene – Recent), Asia (Middle Pleistocene – Recent), Northern America (Late Pleistocene – Recent), Africa (Late Pleistocene).

The studied fossil material was evaluated without regard to the circumstances of their discovery. All measurements in the tables are in millimetres.

The Lisková Cave

The studied material consists of two upper jaw fragments with I^3 dex. and sin., C sup. dex. and sin., P^4 dex. and sin., M^1 dex. and sin., M^2 dex., and with I^1, I^2, P^1, P^2, P^3 dex. and sin., and M^2 sin. alveoli (Photo 1), the fragment of skull and four mandible fragments. The colour of the teeth crowns is white-brown and yellow-brown, the colour of roots is yellow and yellow-brown and the colour

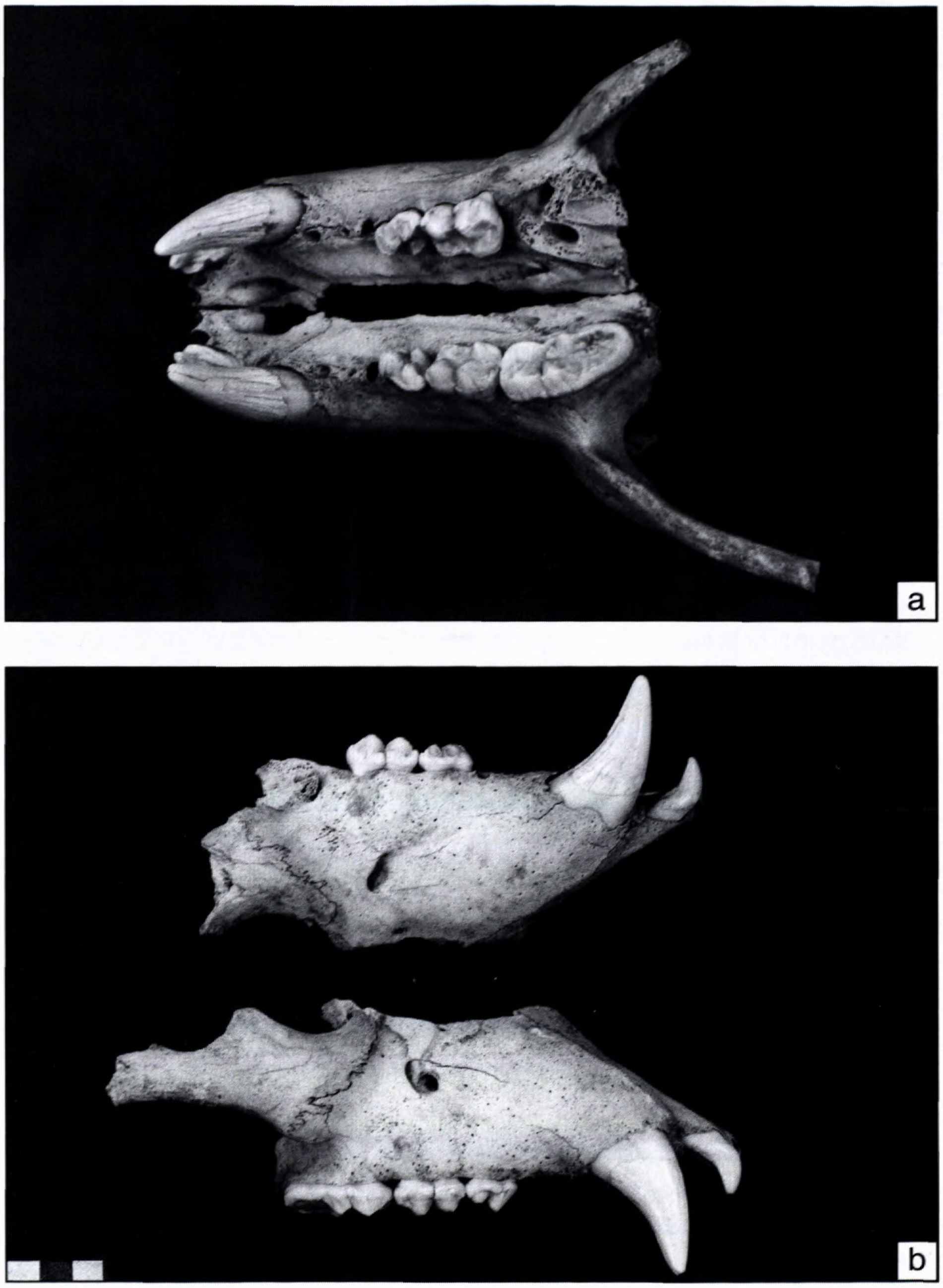

Photo 1. *Ursus arctos* cf. *priscus* GOLDFUSS, 1822 – the upper jaw of the adult individual (No. 751/2 and 751/3), Lisková Cave, the Last Glacial, 1/2 – 1/3 of the natural size (a – palate view, b – lateral view) (photo: V. Klimešová).

of cranium fragments is yellow, yellow-brown, brown and grey-white.

The both right (No. 751/2) and left (No. 751/3) third upper incisors are still situated in two fragments of upper jaw, probably belongs to brown bear male. Their crowns are damaged, especially on the base; abraded on the top of the main cusps; and with distinct cingulum on the antero-lingual side. The measurements of these incisors are as follows: the crown height is 16 mm (right incisor) and 16.2 mm (left incisor); the lengthwise crown average is 15.1 mm (right incisor) and 15 mm (left incisor); and the transverse crown average is 15.2 mm (right incisor) and 15.2 mm for left incisor.

The right upper canine (No. 751/2; see Tab. 3) has crown damaged and abraded, but the one of the left upper canine (No. 751/3; see Tab. 3) is only damaged at its surface, especially in the crest area.

The crown of the fourth right upper premolar (No. 751/2; see Tab. 4) faintly damaged and abraded. The paracone is damaged on the top together with the metacone, which has one accessory cusp at the back. The deuterocone has not developed an accessory cusp. The cingulum is distinct. The fourth left upper premolar (No. 751/3; see Tab. 4) has a damaged and unabraded crown. The paracone together with metacone are damaged on the outside. One accessory cusp is situated behind the metacone. The distinct deuterocone is undamaged and unabraded, without an accessory cusp. The walls of main cusps are smooth. The cingulum is distinctly developed, especially at the back and in the front.

The first right upper molar (No. 751/2; see Tab. 6) has crown damaged and abraded. The both paracone and metacone are damaged on the top, and their accessory cusps (parastyle and metastyle) are abraded together with the protocone and cusp, which is situated between the protocone and hypocone (metaconuluse). The hypocone is still distinct together with the crown cingulum. The middle part of this molar is abraded. The crown of the first left upper molar (No. 751/3; see Tab. 6) is damaged too, and faintly abraded. The paracone is damaged on the top, smooth on the inside, with a parastyle in the front, and separated from the metacone by a notch. As well, the metacone is damaged on the top, smooth on the inside, and with little metastyle at the back, forming the end of the posterior crest. The protocone is not divided and faintly abraded. The hypocone is without accessory cusps, and is faintly abraded, similarly the lesser metaconuluse. The middle part of crown is smooth, without cusps. The cingulum is developed on both lateral sides, but the lingual one is more robust.

Tab. 1. Measurements and counted indices of the fossil and subfossil brown bear skulls from some studied localities.

skulls	***Ursus arctos arctos*** **Lukáč Abyss (4525)**
skull length (from the anterior-most point of skull to the posterior border of occipital condyles)	334.2
max. skull length	357.0
skull length (from the anterior-most point of skull to the lower border of foramen magnum)	316.6
length of the face part of the skull	261.7
length of the cerebral part of the skull	115.3
medium length of the nasal bones	-
lateral length of the nasal bones	-
palate length	177.9
length (from the posterior border of the palate to the posterior border of the pterygoid hamulus)	69.0
rostrum width	87.4
zygomatic width	226.2
interorbital width	80.7
postorbital width	-
mastoid width	161.8
skull height	190.4 (with mandible)
height of the upper canines	-
length from the upper P4 to the upper M2: dex.	74.8
length from the upper P4 to the upper M2: sin.	73.7
the same in % of the max. skull length: dex.	21.0
the same in % of the max. skull length: sin.	20.6
frontal width	120.0
length from the upper canine to the upper M2: dex.	131.0
length from the upper canine to the upper M2: sin.	135.0
the same in % of the max. skull length: dex.	36.7
the same in % of the max. skull length: sin.	37.8

skulls	***Ursus arctos priscus*** **Važec Cave (570/77)**
skull length (from the anterior-most point of skull to the posterior border of occipital condyles)	314.2
max. skull length	347.7
skull length (from the anterior-most point of skull to the lower border of foramen magnum)	294.4
length of the face part of the skull	258.0
length of the cerebral part of the skull	108.0
medium length of the nasal bones	81.0
lateral length of the nasal bones	87.5
palate length	171.5
length (from the posterior border of the palate to the posterior border of the pterygoid hamulus)	70.4
rostrum width	76.3
zygomatic width	-
interorbital width	-
postorbital width	68.5
mastoid width	172.9
skull height	-
height of the upper canines	48.4 (dex.)
length from the upper P4 to the upper M2: dex.	70.4
length from the upper P4 to the upper M2: sin.	72.4
the same in % of the max. skull length: dex.	20.3
the same in % of the max. skull length: sin.	20.8
frontal width	112.0
length from the upper canine to the upper M2: dex.	120.0
length from the upper canine to the upper M2: sin.	118.6
the same in % of the max. skull length: dex.	34.5
the same in % of the max. skull length: sin.	34.1

skulls	*Ursus arctos* cf. *priscus* Vyvieranie Cave (321)
skull length (from the anterior-most point of skull to the posterior border of occipital condyles)	402.3
max. skull length	415.0
skull length (from the anterior-most point of skull to the lower border of foramen magnum)	390.0
length of the face part of the skull	336.4
length of the cerebral part of the skull	101.8
medium length of the nasal bones	-
lateral length of the nasal bones	-
palate length	230.0
length (from the posterior border of the palate to the posterior border of the pterygoid hamulus)	-
rostrum width	100.0
zygomatic width	-
interorbital width	-
postorbital width	89.2
mastoid width	-
skull height	-
height of the upper canines	-
length from the upper P4 to the upper M2: dex.	97.0
length from the upper P4 to the upper M2: sin.	97.0
the same in % of the max. skull length: dex.	24.1
the same in % of the max. skull length: sin.	24.1
frontal width	126.9
length from the upper canine to the upper M2: dex.	176.0
length from the upper canine to the upper M2: sin.	176.0
the same in % of the max. skull length: dex.	43.8
the same in % of the max. skull length: sin.	43.8

Tab. 2. Measurements and counted indices of the fossil and subfossil brown bear mandibles from some studied localities (* - measured only to m1, (a) – alveolusly measured).

mandibles	*Ursus arctos arctos*, Lukáč Abyss (4526)		*U. arctos* cf. *arctos* Šípová Cave (6310)
mandible length	245.7 (dex.)	247.5 (sin.)	183..6
height of the C inf.	-	-	30.7
length of the P4 - M3	82.1 (dex.)	80.8 (sin.)	75.0 (a)
length of the P4 - M3 in % of the mandible length	33.4 (dex.)	32.7 (sin.)	40.8
length of the C inf. - M3	147.0 (dex.)	147.3 (sin.)	118.3 (a)
length of the C inf - M3 in % of the mandible length	59.8 (dex.)	59.5 (sin.)	64.4
max. mandible height	-	-	79.8
upper mandible width		143.5	-
lower mandible width		179.0	-

mandibles	*Ursus arctos* ssp., Psie diery Cave	
	5815/dex.	5815/sin.
mandible length	107.4	104.4
height of the C inf.	10.2	-
length of the P4 - M3	31.0*	59.6 (a)
length of the P4 - M3 in % of the mandible length	28.9*	57.1
length of the C inf. - M3	53.4*	80.0 (a)
length of the C inf - M3 in % of the mandible length	49.7*	76.6
max. mandible height	41.0	-
upper mandible width	-	-
lower mandible width	-	-

The brown crown of the second right upper molar (No. 751/2; see Tab. 7) is undamaged and nearly unabraded. The paracone has developed one accessory cusp on the front side, but the metacone is without an accessory cusp. The protocone is divided into two cusplets, the metaconuluse is distinct and the hypocone coincides with the back border of the crown. The middle part of the crown is faintly abraded.

The seams of the damaged skull fragment (No. 751/1) are fully grown and knitted together (adult individual). The occipital shield is damaged in the upper part of the nuchal crest, on the base and in the area of the jugular processes. The basisphenoid is broken off. The temporals are damaged, especially on the base and in the area of the mastoid processes, but both right and left mandible fossa are undamaged. The parietals are damaged; the sagittal crest, that is beginning most on the skull end, is very faint and short. Only posterior part of the frontals has been preserved. Also, the lateral parts fragments of the pterygoid are preserved only. The measurements of this skull fragment are as follows: the braincase width is 120.6 mm and the mastoid width is 161.5 mm.

Only posterior parts of two right and two left mandible branches have been studied (No. 582/1-2 and No. 583/1-2). They have broken off coronoid process and damaged the condylar process. The angular process is either damaged or broken off; with two distinct lengthwise crests in the inside. One mandible fragment with M_2 dex. and M_3 dex. alveoli has both undamaged the mandible foramen and the subangular process. The length between the coronoid process and angular process of the mandible fragment No. 582/1 is 49.5 mm and of the mandible fragment No. 583/1 is 52.6 mm.

The studied findings belong to five to six adult individuals. One of them was probably male. On the basis of the metric and morphologic characteristics of these bear fossil remains, especially fragments of upper jaw with P^1, P^2 and P^3 alveoli, they were placed into the taxon *Ursus arctos* cf. *priscus*.

The Lukáč Abyss

The skull (No. 4525 (18/86); see Photo 2) and mandible (No. 4526; see Photo 2) from the Lukáč Abyss belong to a subfossil representative of the brown bear. The measurements of the both skull and mandible are situated in the tables No. 1 and 2.

There are preserved only the fourth upper premolars and the first and second upper molars in the upper jaws (see Tabs. 4, 6 and 7). In the mandible, both the fourth both right and left lower premolars (see Tab. 5), the first left lower molar, both the second right and left lower molars (see Tab. 8), and the third right lower molar have been preserved there.

The first left lower molar (No. 4525) is very damaged. The length of this tooth is 21.2 mm, and the width at the back narrow of this one is 5.4 mm. The measurements of the abraded third right lower molar (No. 4525) are as follows: the tooth length is 19.4 mm; the width in the frontal part is 15.4 mm; the width at the back part is 15.2 mm; and crown height at the place of the paraconid is 4.2 mm.

As well, four free canines (1 C sup. dex., 1 C sup. sin., 1 C inf. dex., and 1 C inf. sin.; see Tab. 3) have been studied. The colour of their crowns is yellow-white and yellow-brown, the colour of their roots is yellow and yellow-brown.

The crown of the right upper canine (No. 4547/1; see Tab. 3) is damaged. Root is preserved entirely and faintly damaged on the surface. The left upper canine (No. 4547/2; see Tab. 3) has its crown abraded on the top and damaged on the surface. Root is preserved entirely and damaged on the surface.

The crown of the right lower canine (No. 4546/2; see Tab. 3) is abraded on the top and damaged on the surface. Root is preserved entirely and faintly damaged on the surface. The left lower canine (No. 4546/1; see Tab. 3) has its crown very damaged, especially on lingual side. Its root is also preserved entirely and damaged on the surface.

All these subfossil bear findings belong to subspecies *Ursus arctos arctos* and probably they belong to old individual, which skeleton have been found in the sinter deposits at the bottom of this abyss. F. Pomorský has partly studied these remains (1986).

The Psie diery Cave

Only one incomplete skull and mandible of the brown bear cub (No. 5815) has been studied from this location. The skull consists only of braincase and the damaged facial part. The width of the brow is 67 mm. This is an only measurement, measured at the damaged skull.

The right branch of the mandible (see Tab. 2) is faintly abraded and damaged on the inner side. This mandible contained one lower canine and a still ingrown permanent first lower molar together with the incisor, and P_1, P_3 and P_4 alveoli.

The left branch of this mandible (see Tab. 2) is also faintly abraded, with a broken off the coronoid process. The P_3, P_4 and M_3 alveoli and, still ingrown, both of the permanent first and second lower molars have been situated here.

On the basis of the presence of the P_1 dex., and P_3 dex. and sin. alveoli, this finding probably belongs to the species *Ursus arctos* LINNÉ.

The Šípová Cave

One fragment of right upper jaw (No. 6311 (114/94)) with the C sup. dex. (see Tab. 3), P^4 dex. (see Tab. 4) and M^1 dex. (see Tab. 6), and the right branch of mandible with C inf. dex. and P_4 dex. from the Šípová Cave probably belongs to subfossil representative of the brown bear.

The light-yellow mandible (No. 6310; see Tab. 2) is faintly damaged on the surface. The sinter crust covers the part of this one. Three chin openings (*foramina mentalia*) are developed in the front mandible part – two of

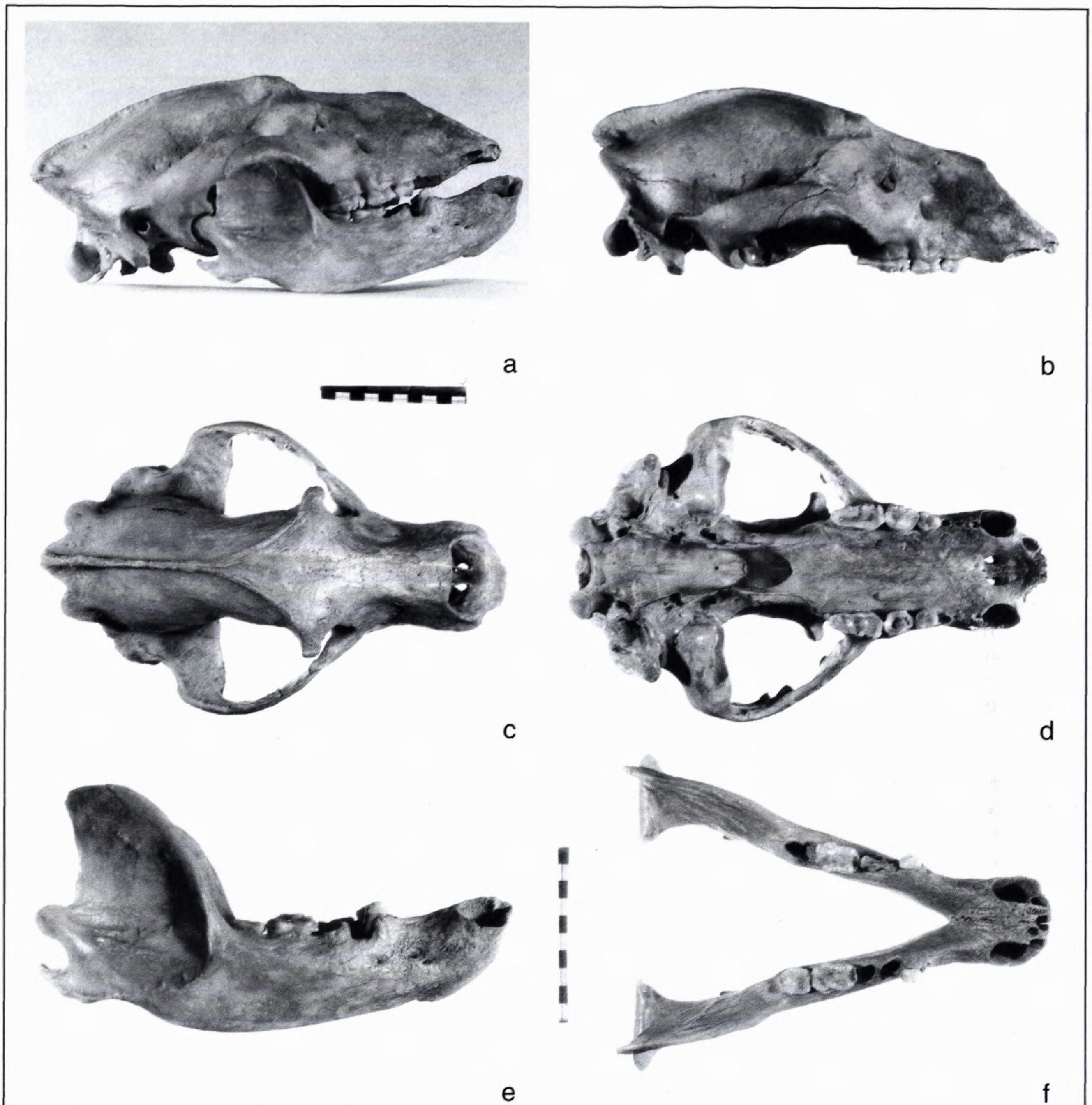

Photo 2. *Ursus arctos arctos* LINNÉ, 1758 – the skull and mandible from the Lukáč Abyss, the end of the Pleistocene (?) and start of the Holocene, 1/3 – 1/4 of the natural size (a – complete view; b – skull, lateral view; c – skull, dorsal view; d – skull, ventral view; e – mandible, lateral view; f – mandible, dorsal view) (photo: L. Osvald).

these are situated below the space between C inf. dex. and P_4 dex., and one small chin opening sits below P_4 dex. This mandible branch with incisors, P_1 dex. and molar alveoli belongs probably to young male individual.

The white and yellow-white crown of the lower right canine of this mandible (No. 6310, see Tab. 3) is damaged on the surface and unabraded. The colour of root is yellow.

The colour of the P_4 crown from the described mandible branch (No. 6310, see Tab. 5) is yellow-white. Its crown is damaged, especially at the back; and only faintly abraded. The protoconid is distinct, faintly abraded at the back, with a distinct anterior cingulum, and with a small accessory cusp on the posterior side where it has developed a low crest. This crest continues to the little cusp (probably hypoconid), situated at the distinct posterior cingulum. The colour of the both roots is yellow.

The Važec Cave

Only one skull of a fossil brown bear was metrically and morphologically studied from this cave. The major

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Tab. 3. Measurements and counted indices of the fossil and subfossil brown bear upper and lower canines from some studied localities.

the upper and lower canines	***U. arctos* cf. *priscus*, Lisková Cave**		***U. a.* cf. *arctos***
sample	**751/2**	**751/3**	**Šípová C. (6311)**
tooth length measured from tip to root tip (not along the length of the tooth)	-	-	-
lengthwise average of the crown base	22.7	21.8	17.6
transverse average of the crown base	16.6	15.2	12.0
transverse average of the crown base in % of the lengthwise average of the crown base	73.1	69.7	68.2
crown height	38.0	34.0	27.6
max. lengthwise root average	-	-	-
max. transverse root average	-	-	-
max. transverse root average in % of the lengthwise root average	-	-	-
root length in front	-	-	-
root length at the back	-	-	-
lengthwise root average in % of the root length at the back	-	-	-
transverse root average in % of the root length at the back	-	-	-

the upper and lower canines	***U. arctos priscus***
sample	**Važec C. (570/77)**
tooth length measured from tip to root tip (not along the length of the tooth)	85.8
lengthwise average of the crown base	20.0
transverse average of the crown base	15.2
transverse average of the crown base in % of the lengthwise average of the crown base	76.0
crown height	24.4
max. lengthwise root average	28.0
max. transverse root average	17.6
max. transverse root average in % of the lengthwise root average	62.9
root length in front	67.0
root length at the back	56.4
lengthwise root average in % of the root length at the back	49.7
transverse root average in % of the root length at the back	31.2

the upper and lower canines	***U. a.* cf. *arctos***	***U. arctos, arctos*, Lukáč Abyss**	
sample	**Šípová C. (6310)**	**4547/1**	**4547/2**
tooth length measured from tip to root tip (not along the length of the tooth)	-	90.7	90.4
lengthwise average of the crown base	19.6	20.0	20.4
transverse average of the crown base	14.7	16.0	16.2
transverse average of the crown base in % of the lengthwise average of the crown base	75.0	80.0	79.4
crown height	30.8	31.5	29.2
max. lengthwise root average	-	22.8	22.8
max. transverse root average	-	16.4	16.7
max. transverse root average in % of the lengthwise root average	-	71.9	73.3
root length in front	-	69.2	70.0
root length at the back	-	56.0	58.0
lengthwise root average in % of the root length at the back	-	40.7	39.3
transverse root average in % of the root length at the back	-	29.3	28.2

the upper and lower canines	U. arctos arctos, Lukáč Abyss	
sample	4546/1	4546/2
tooth length measured from tip to root tip (not along the length of the tooth)	84.8	83.0
lengthwise average of the crown base	21.0	20.3
transverse average of the crown base	16.5	16.4
transverse average of the crown base in % of the lengthwise average of the crown base	78.6	80.8
crown height	31.7	28.8
max. lengthwise root average	22.6	22.5
max. transverse root average	16.4	16.0
max. transverse root average in % of the lengthwise root average	72.6	71.1
root length in front	64.5	65.0
root length at the back	52.2	52.0
lengthwise root average in % of the root length at the back	43.3	43.3
transverse root average in % of the root length at the back	31.4	30.8

Tab. 4. Measurements and counted indices of the fossil and subfossil brown bear P^4 from the some studied localities.

the fourth upper premolars	U. arctos cf. priscus. Lisková Cave		U. arctos arctos, Lukáč Abyss	
sample	751/2	751/3	4525/dex.	4525/sin.
max. length	17.2	18.0	16.9	17.6
max. width	13.0	13.6	13.5	12.5
max. width in % of the max. length	75.6	75.6	79.9	71.0
crown height at the place of the paracone	10.5	-	8.7	7.0
max. width in % of the paracone length	118.2	138.8	129.8	125.0
paracone length	11.0	9.8	10.4	10.0
metacone length	8.4	4.7	7.4	7.2
deuterocone length	7.6	7.8	8.3	9.2
metacone length in % of the paracone length	76.4	48.0	71.2	72.0
deuterocone length in % of the paracone length	69.1	79.6	79.8	92.0
deuterocone length in % of the metacone length	90.5	166.0	112.2	127.8

the fourth upper premolars sample	U. arctos cf. arctos Šípová C. (6311)	U. a. priscus Važec C. (570/77)	U. a. cf. priscus Vyvieranie C. (321)
max. length	15.4	17.2	22.4
max. width	10.1	12.6	13.8
max. width in % of the max. length	65.6	73.3	61.6
crown height at the place of the paracone	8.4	8.3	7.4
max. width in % of the paracone length	113.5	126.0	-
paracone length	8.9	10.0	-
metacone length	5.6	7.3	-
deuterocone length	7.5	8.0	-
metacone length in % of the paracone length	62.9	73.0	-
deuterocone length in % of the paracone length	84.3	80.0	-
deuterocone length in % of the metacone length	133.9	109.6	-

Tab. 5. Measurements and counted indices of the subfossil brown bear P_4 from the some studied localities.

the fourth premolars	U. arctos arctos, Lukáč Abyss			U. a. cf. arctos
samples	4525/dex.	4525/sin.	average	Šípová Cave (6310)
max. lenght	12.6	12.0	12.3	11.3
max. width	7.7	8.0	7.9	5.8
max. width in % of the max. lenght	61.1	66.7	63.9	51.3
crown height at the place of the protoconid	5.5	6.0	5.8	6.2

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Tab. 6. Measurements and counted indices of the fossil and subfossil brown bear M^1 from the some studied localities

the first upper molars	***U. arctos* cf. *priscus*, Lisková Cave**		***U. a. arctos*, Lukáč A.**
sample	**751/2**	**751/3**	**4525/d**
max. length	24.6	23.4	24.6
width of the frontal part	16.0	15.8	15.5
width of the frontal part in % of the max. length	65.0	67.5	63.0
width of the back part	15.6	18.0	17.8
width of the back part in % of the max. length	63.4	76.9	72.4
width of the back part in % of the width of the frontal part	97.5	113.9	114.8
width of the middle part	-	15.4	15.8
length of the frontal part measured at the middle	9.6	10.2	11.2
length of the back part measured at the middle	12.4	12.4	12.3
length of the back part in % of the length of the frontal part	129.2	121.6	109.8
width of the frontal part in % of the length of the frontal part	166.7	154.9	138.4
width of the back part in % of the length of the back part	125.8	145.2	144.7
paracone length	9.0	8.8	8.8
paracone length in % of the tooth length	36.6	37.6	35.8
metacone length	8.9	10.3	10.1
metacone length in % of the tooth length	36.2	44.0	41.1
metacone length in % of the paracone length	98.9	117.1	114.8
crown height at the place of the paracone	9.0	9.0	4.5
crown height at the place of the paracone in % of the tooth length	36.6	38.5	18.3
crown height at the place of the metacone	9.7	10.2	6.1
crown height at the place of the metacone in % of the tooth length	39.4	43.6	24.8

the first upper molars	***U. a. arctos*, Lukáč's A.**	***U. arctos* cf. *arctos***	***U. a. priscus*, Važec C.**
sample	**4525/s**	**Šípová C. (6311)**	**570/77/dex.**
max. length	22.0	21.2	22.0
width of the frontal part	13.7	14.4	16.2
width of the frontal part in % of the max. length	62.3	67.9	73.6
width of the back part	17.0	16.4	17.3
width of the back part in % of the max. length	77.3	77.4	78.6
width of the back part in % of the width of the frontal part	124.1	113.9	106.8
width of the middle part	15.1	14.6	16.0
length of the frontal part measured at the middle	8.9	9.0	10.0
length of the back part measured at the middle	13.0	11.8	11.2
length of the back part in % of the length of the frontal part	146.1	131.1	112.0
width of the frontal part in % of the length of the frontal part	153.9	160.0	162.0
width of the back part in % of the length of the back part	130.8	139.0	154.5
paracone length	6.2	9.3	9.2
paracone length in % of the tooth length	28.2	43.9	41.8
metacone length	11.4	9.4	9.0
metacone length in % of the tooth length	51.8	44.3	40.9
metacone length in % of the paracone length	183.9	101.1	97.8
crown height at the place of the paracone	-	8.6	6.8
crown height at the place of the paracone in % of the tooth length	-	40.6	30.9
crown height at the place of the metacone	5.7	9.2	7.4
crown height at the place of the metacone in % of the tooth length	25.9	43.4	33.6

the first upper molars sample	*U. a. priscus,* Važec C. 570/77/sin.	*U. arcos* cf. *priscus* 321/dex.	Vyvieranie Cave 321/sin.
max. length	21.2	31.5	31.8
width of the frontal part	15.8	21.8	21.5
width of the frontal part in % of the max. length	74.5	69.2	67.6
width of the back part	16.4	20.8	21.6
width of the back part in % of the max. length	77.4	66.0	67.9
width of the back part in % of the width of the frontal part	103.8	95.4	100.5
width of the middle part	15.9	20.5	20.5
length of the frontal part measured at the middle	11.0	-	14.5
length of the back part measured at the middle	11.5	-	16.0
length of the back part in % of the length of the frontal part	104.6	-	110.3
width of the frontal part in % of the length of the frontal part	143.6	-	148.3
width of the back part in % of the length of the back part	142.6	-	135.0
paracone length	9.0	12.3	12.6
paracone length in % of the tooth length	42.5	39.1	39.6
metacone length	8.4	11.6	12.2
metacone length in % of the tooth length	39.6	36.8	38.4
metacone length in % of the paracone length	93.3	94.3	96.8
crown height at the place of the paracone	7.0	-	-
crown height at the place of the paracone in % of the tooth length	33.0	-	-
crown height at the place of the metacone	7.0	-	-
crown height at the place of the metacone in % of the tooth length	33.0	-	-

Tab. 7. Measurements and counted indices of the fossil and subfossil brown bear M^2 from the some studied localities.

the second upper molars sample	*U. arctos* cf. *priscus* Lisková C. (751/2)	*U. a. arctos,* Lukáč Abyss 4525/dex.	 4525/sin.
max. tooth length	38.4	36.0	37.5
width at the place of the paracone (with cingulum)	18.0	18.6	19.2
width at the place of the hypocone	14.3	13.7	14.4
paracone length	10.5	11.0	12.3
metacone length	10.7	11.4	11.0
width at the place of the paracone in % of the max. tooth length	46.9	51.7	51.2
metacone length in % of the paracone length	101.9	103.6	89.4

the second upper molars sample	*U. a. priscus.* 570/77/dex.	Važec Cave 570/77/sin.
max. tooth length	32.3	35.0
width at the place of the paracone (with cingulum)	18.5	18.2
width at the place of the hypocone	11.8	13.0
paracone length	13.0	10.2
metacone length	7.6	9.9
width at the place of the paracone in % of the max. tooth length	57.5	52.0
metacone length in % of the paracone length	58.5	97.0

the second upper molars sample	*U. a.* cf. *priscus* 321/dex.	Vyvieranie Cave 321/sin.
max. tooth length	46.2	46.8
width at the place of the paracone (with cingulum)	24.2	25.0
width at the place of the hypocone	19.4	19.8
paracone length	13.6	13.9
metacone length	9.9	-
width at the place of the paracone in % of the max. tooth length	52.4	53.4
metacone length in % of the paracone length	72.8	-

part of this skull (No. 570/77; see Tab. 1) is covered by the sinter crust. The left zygomatic arch of this grey skull is broken off and its sagittal crest is good developed. Only C sup. dex., P^4 dex., M^1 dex. and sin., M^2 dex. and sin.; and P^1 dex. and P^3 dex. alveoli are preserved. The presence of these front upper premolar alveoli indicates the subspecies of brown bear from the Last Glacial (*Ursus arctos priscus* GOLDFUSS). The white crowns of the teeth are abraded. The measurements of canine, premolar and molars are situated in the table No. 3, 4, 6 and 7.

The Vyvieranie Cave

Only one skull of a fossil brown bear from this cave was studied metrically and morphologically. The skull (No. 321, see Tab. 1) is incomplete and very damaged. The zygomatic arches together with the back part of the cranium base are broken off and the external narial aperture is damaged. Only P^4 sin., M^1 dex. and sin., and M^2 dex. and sin. have been preserved of the upper teeth (see Tabs. 4, 6 and 7). Their white and brown crowns are very abraded. The cave bears have found their third upper premolars only exceptionally. Therefore, the presence of the alveolus of this upper premolar at the left part of studied skull indicated that this one probably is a fossil representative of the brown bear from the Last Glacial (*Ursus arctos* cf. *priscus*).

Discussion and conclusions

On the basis of the metric and morphologic analyses of the described remains from the studied locations, we are able to discuss and draw conclusions on the findings.

The fossil findings from the Lisková Cave belong to brown bears, probably from the Last Glacial Period. The evidence of it is the arctoid morphology of the cranium (presence of P^{1-3} alveoli, low and short sagittal crest etc.) and mandibles fragments together with morphology and measurements of the teeth. These teeth are similar to the bear teeth from the Lukáč Abyss and they correspond metrically to the findings from the Hundsheim (*Ursus deningeri*) (Musil, 1972), Předmostí (*Ursus arctos priscus*) (Musil, 1964), Važec Cave (*Ursus arctos priscus*) and Kupčovie izbička Cave (*Ursus arctos* cf. *priscus*) (see Tab. 9). However, the measurements of these teeth are larger than teeth measurements of the recent brown bears from Europe (*Ursus arctos arctos*). On the basis of it, we can assume that this studied material belongs to the representatives of the species *Ursus arctos*, probably of the subspecies *priscus* (*Ursus arctos* cf. *priscus*).

From the metrical and morphological point of view, the skull from the Lukáč Abyss belongs to the subfossil subspecies *Ursus arctos arctos* LINNÉ. The morphology and teeth measurements also confirm this result. From the metrical point of view these teeth correspond to the measurements of bear teeth from the Važec Cave (*Ursus arctos priscus*) and the Lisková Cave. We can also see some metric similarity in the findings from Bilzingsleben (Musil, 1991), Žernavá (Musil, 1969), and the Bear Cave in Slovenský raj Mountains (Sabol, *in press*) (see Tab. 9). These findings probably belong to individual, which skeleton has partly studied by Pomorský (1986). It was relatively large, but older and sick male too (there have been ascertained spondylosis, fractures and other pathological phenomena on its bones). These osteological remains is possible to date probably to the period from the end of the Pleistocene (?) to the beginning of the Holocene.

The damaged skull together with mandible from the Psie diery Cave belongs probably to a cub of the taxon *Ursus arctos* ssp. In this case, skull morphology played the decisive role in the species determination, especially due to the presence of P_1 and P_3 alveoli in both mandible branch only (P_1 was developed in the right branch of mandible only), though the presence of front premolars is known from findings of cave bear juveniles too. This bear cub must have perished in the first year of its life. The evidence of this is presence in the still ingrown permanent lower molars.

From the metrical point of view, the teeth (C sup., P^4 and M^1) situated in the fragment of right upper jaw from the Šípová Cave correspond to the findings from the Pod hradem Cave (Musil, 1965), the Bear Cave under Sivý hill (= „v Sypkých skalách“ Cave), also, these teeth correspond to tooth measurements of the subspecies *Ursus arctos priscus* from the Važec Cave (see Tab. 9). However, the typical arctoid morphology of molar was an important finding for the final determination of the species. Also, the morphology and measurements of the right mandible and its teeth (C inf. dex. and P_4 dex.) indicate a typical representative of the brown bears. On the basis of this, the findings have been placed in the species *Ursus arctos* LINNÉ, probably subspecies *arctos*.

The measurements of the skull (No. 570/77) from the Važec Cave correspond to the observed range of the species *Ursus arctos*. However from the morphological point of view, this bear skull shows arctoid features as well as speleoid ones such as a weakly vaulted brow and a distinctly developed sagittal crest, typical for cave bears. From the morphological point of view, the teeth correspond to the morphology of teeth of bears from the arctoid branch of the ursid phylogeny. On the other hand, from the metric point of view the skull teeth correspond to the measurements of *Ursus spelaeus* teeth as well as the measurements of *Ursus arctos* teeth, though some correspond more to the measurements of brown bear teeth. The metrical similarity with findings from the Lukáč Abyss, the Bear Cave under Sivý hill and the Lisková Cave (see Tab. 9) is evidence of this. On the basis of these signs it was determined that this bear skull belongs to a representative of the subspecies *Ursus arctos priscus* GOLDFUSS.

Besides speleoid features, the bear skull from the Vyvieranie Cave shows features, which are typical for the arctoid branch of ursid phylogeny. From the morphologic and metric point of view, the teeth of this skull have a speleoid character and they correspond to the measurements of findings from the Pod hradem Cave (Musil, 1965) and Švédův stůl Cave (Musil, 1962) in Moravia (see Tab. 9). However, on the basis of presence of the P^3

Tab. 8. Measurements and counted indices of the subfossil brown bear M_2 from the Lukáč Abyss.

the second lower molars	***U. a. arctos*, Lukáč Abyss**	
sample	**4525/dex.**	**4525/sin.**
tooth length	25.4	26.7
width of the frontal part	15.7	15.5
width of the frontal part in % of the tooth length	61.8	58.1
width of the back part	17.4	17.7
width of the back part in % of the tooth length	68.5	66.3
width of the back part in % of the width of the frontal part	110.8	114.2
frontal part length on the lingual side	12.4	12.3
frontal part length on the lingual side in % of the tooth length	48.8	46.1
back part length on the lingual side	13.0	13.2
back part length on the lingual side in % of the tooth length	51.2	49.4
back part length on the lingual side in % of the frontal part length on the lingual side	104.8	107.3
frontal part length on the buccal side	15.8	17.0
frontal part length on the buccal side in % of the tooth length	62.2	63.7
back part length on the buccal side	9.2	9.4
back part length on the buccal side in % of the tooth length	36.2	35.2
back part length on the buccal side in % of the frontal part length on the buccal side	58.2	55.3
crown height at the place of the protoconid	5.0	3.7
crown height at the place of the protoconid in % of the tooth length	19.9	13.9
crown height at the place of the metaconid	6.2	6.2
crown height at the place of the metaconid in % of the tooth length	24.4	23.2
crown height at the place of the hypoconid	5.0	3.8
crown height at the place of the hypoconid in % of the tooth length	19.9	14.2
crown height at the place of the entoconid	5.0	6.2
crown height at the place of the entoconid in % of the tooth length	19.9	23.2

Tab. 9. The comparison of some measurements of bear teeth from described localities with measurements adduced by the other authors.

fossil and subfossil remains of the bears		**Bilzingsleben**	**Hundsheim**	**Žernavá**	**Švédův stůl (Musil, 1962)**	
		(Musil, 1991)	(Musil, 1972)	(Musil, 1969)	*Ursus spelaeus*	
		U. deningeri	*U. deningeri*	*U. deningeri*	R/W + W1-2	W2
		average	average		average	average
the fourth upper premolars	max. length	18.4	18.1	19.4	20.6	20.9
	max. width	13.2	12.8	14.1	14.0	14.5
the first upper molars	max. length	26.1	-	-	29.2	29.1
	width of the frontal part	18.2	-	-	19.7	19.5
the second upper molars	max. length	42.4	-	42.0	46.1	46.4
	width at the place of the paracone	21.3	-	18.9	23.1	22.5
the fourth lower premolars	max. length	14.2	-	-	-	15.7
	max. width	9.2	-	-	-	10.7
the first lower molars	max. length	28	-	27.3	31.1	31.1
	talonid length	13.9	-	13.2	14.0	14.8
the second lower molars	max. length	29.1	-	-	32.0	31.1
	width of the back part	17.7	-	-	18.9	19.0
the third lower molars	max. length	26	-	-	28.1	28.0
	max. width	18.4	-	-	19.7	20.4

fossil and subfossil remains of the bears		**Pod hradem (Musil, 1965) *Ursus spelaeus***			
		W2 - W3	W1-2		W1
		I.	II.	III.	IV.
		average	average	average	average
the fourth upper premolars	max. length	19.8	20.8	20.7	-
	max. width	14.5	14.4	14.8	-
the first upper molars	max. length	29.2	29.0	27.8	-
	width of the frontal part	20.3	19.6	18.6	-
the second upper molars	max. length	44.4	45.7	44.8	-
	width at the place of the paracone	22.4	23.3	22.5	-
the fourth lower premolars	max. length	15.0	15.8	16.1	15.7
	max. width	10.6	10.8	10.7	10.2
the first lower molars	max. length	30.0	30.7	30.7	29.4
	talonid length	14.2	14.6	14.9	14.2
the second lower molars	max. length	31	31.5	31.2	29.9
	width of the back part	18.3	18.5	18.5	18.4
the third lower molars	max. length	26.7	28.1	27.7	27.2
	max. width	18.9	19.8	20.0	19.1

fossil and subfossil remains of the bears		**Předmostí** (Musil,1964) *U. a. priscus*	**"v Sypkých skalách"** *U. spelaeus*	**Kupčovie izbička** *U. a.* cf. *priscus*	**Lisková Cave** *U. a.* cf. *priscus*
		average	average	average	average
the fourth upper premolars	max. length	15.0	17.1	16.3	17.6
	max. width	9.0	12.2	12.4	13.3
the first upper molars	max. length	24.2	26.8	25.2	24.0
	width of the frontal part	17.4	17.0	16.4	15.9
the second upper molars	max. length	38.3	42.0	38.3	38.4
	width at the place of the paracone	+20.6	19.8	19.0	18.0
the fourth lower premolars	max. length	-	15.2	-	-
	max. width	-	11.2	-	-
the first lower molars	max. length	27.1	32.8	25.7	-
	talonid length	14.2	-	9.0	-
the second lower molars	max. length	28.8	31.6	25.5	-
	width of the back part	17.9	20.3	16.8	-
the third lower molars	max. length	24.2	-	-	-
	max. width	17.3	-	-	-

fossil and subfossil remains of the bears		**Lukáč Abyss** *U. a. arctos*	**Šípová Cave** *U. a.* cf. *arctos*	**Važec Cave** *U. a. priscus*	**Vyvieranie** *U. a.* cf. *priscus*
		average		average	
the fourth upper premolars	max. length	17.3	15.4	17.2	22.4
	max. width	13.0	10.1	12.6	13.8
the first upper molars	max. length	23.3	21.2	21.6	31.7
	width of the frontal part	14.6	14.1	16.0	21.7
the second upper molars	max. length	36.8	-	33.7	46.5
	width at the place of the paracone	18.9	-	18.4	24.6
the fourth lower premolars	max. length	12.3	11.3	-	-
	max. width	7.9	5.8	-	-
the first lower molars	max. length	21.2	-	-	-
	talonid length	-	-	-	-
the second lower molars	max. length	26.1	-	-	-
	width of the back part	17.6	-	-	-
the third lower molars	max. length	19.4	-	-	-
	max. width	15.4	-	-	-

alveolus, this fossil remain has been places into the taxon *Ursus arctos* cf. *priscus*.

In conclusion, we are able to determine that the findings of brown bears from Slovak cave sediments dated from the Last Glacial to the start of the Holocene Period belong to the species *Ursus arctos*, tangibly to the subspecies *Ursus arctos priscus* GOLDFUSS (from the Last Glacial; the Lisková Cave, the Važec Cave and the Vyvieranie Cave), the *Ursus arctos arctos* LINNÉ (the Lukáč Abyss) or *Ursus arctos* cf. *arctos* resp. (the Šípová Cave) and to the nearly undetermined subspecies *Ursus arctos* ssp. (the Psie diery Cave).

The presence of these brown bear taxa in our territory is result of some migration waves of these ursids from the south (probably from the Balkan Peninsula) – the extinct *Ursus arctos priscus* appears at the end of the Pleistocene Period, when lived in the same territory together with cave bears, and the *Ursus arctos arctos* is present in our territory by the start of the Holocene or yet by the end of the Last Glacial Period. However, the subspecies *Ursus arctos priscus* is not a descendant of brown bears (*U. arctos arctos*) from southern Europe (Musil, 1996).

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New methods in foraminiferal and calcareous nannoplankton analysis and evolution of Oligocene and Miocene basins of the Southern Slovakia

KATARÍNA HOLCOVÁ

Institute of Geology and Paleontology, Charles University, Albertov 6, 128 43 Praha 2, Czech Republic,
E-mail: Holcová@mail.natur.cuni.cz

Abstract. New methods in the study of foraminiferal and calcareous nannoplankton assemblages enable to distinguish and paleoecologically and paleogeographically interpret nine time intervals in the marine evolution of the South Slovak depressions. Kiscellian represents tectonically inactive period with good correlatin between local and global sea-level changes and widespread occurrence of low-oxic facies. Tectonic activity is evident during the Egerian. Basin morphology gradually changed from the Buda Basin to the Fiľakovo /Pétervásara Basin and communication with the East Slovak Basin was opened. Local sea-level changes cannot be correlated with global ones. Displacement of the Kiscellian and Egerian foraminiferal assemblages around the Plešivec-Rapovce Fault can be observed. Eggenburgian evolution of the basin is characterized by weak influence of tectonic activity and local and global sea-level changes can be correlated. Changes in basin morphology can be observed in the Eggenburgian when communication with Bánovce Depression was opened. During the Ottnangian, rearrangment of basin geometry from the Fiľakovo/Pétervásara Basin to Novohrad/Nógrád Basin was finished. Communication with open sea was realized across the Várpalota area. The Karpatian represented tectonically inactive period with good correlation between local and global sea-level changes. Specific evolution of the South Slovak depressions is observable around the Karpatian / Badenian boundary; it may be connected with the initiation of volvanic activity. Early Badenian transgression occurred later in the South Slovak depressions than in other Central Paratethys basins.

Key words: South Slovak depressions, Tertiary, Foraminifera, calcareous nannoplankton, paleogeography

Introduction

The South Slovak depressions represents an area with very good level of standard biostratigraphic, litostratigraphic and sedimentological analysis summarized by Vass et al. 1979, 1983, 1986, 1989, 1992. The principal results are shown in Fig. 1. Lithostratigraphical units were defined by Vass and Elečko (1982). Correlation with standard nannoplankton zones (Martini, 1971) was done by Lehotayová (1982). Paleogeographical maps were constructed for every stage for the Ipeľ a Rimava Depressions (Vass et al., 1979, 1989). Important tectonic events were distinguished (Vass et al., 1993; Márton et al. 1995; Vass 1995). Local sea-level changes were correlated with global changes (Vass, 1995). In the analysed time interval, radiometric ages were determined for the Lower Miocene only (Vass et al., 1971; Vass and Bagdarasjan, 1978; Vass et al., 1985, 1987; Vass and Balogh, 1986; Repčok, 1987; Kantor et al., 1988 in Vass et al., 1992).

The above mentioned level of knowledges enables to test possible application of new methods of micropaleontological study on precise biostratigraphy, paleoecology, paleogeography and tectonic evolution of the Basin.

The aim of this paper is to show synthesis of results obtained by the use of new micropaleontological methods in deciphering the evolution of marine basins in the Oligocene and Miocene of the South Slovak depressions.

1. Study area

Geomorphological unit called South Slovak depressions consists of 3 partial depressions: Ipeľ, Rimava and Lučenec. It was a part of three marine basins during the Oligocene and Miocene (Vass, 1995):

(1) Buda Basin (Oligocene - Egerian/Eggenburgian boundary); the South Slovak depressions represents northern part of the Buda Basin;

(2) Fiľakovo/Pétervásara Basin (Eggenburgian); the South Slovak depressions was situated in the southern margin of this basin;

(3) Novohrad/Nógrád Basin (Ottnangian-Karpatian), the northern margin of which was represented by the South Slovak depressions.

The Lower Badenian transgression penetrated from the Danube Basin to the area of the South Slovak depressions and the Basin represented eastern margin of this marine basin.

Area of the South Slovak depressions was flooded by the following prominent marine transgresions: the Kiscellian-Egerian, the Eggenburgian, the Ottnangian-Karpatian and the relatively short Lower Badenian transgression. The long-lasting emergence was recorded during the Upper Eggenburgian and Ottnangian, an episodic one during the Upper Karpatian.

Lithostratigraphic units were defined for the Oligocene and Miocene fill of the South Slovak depressions

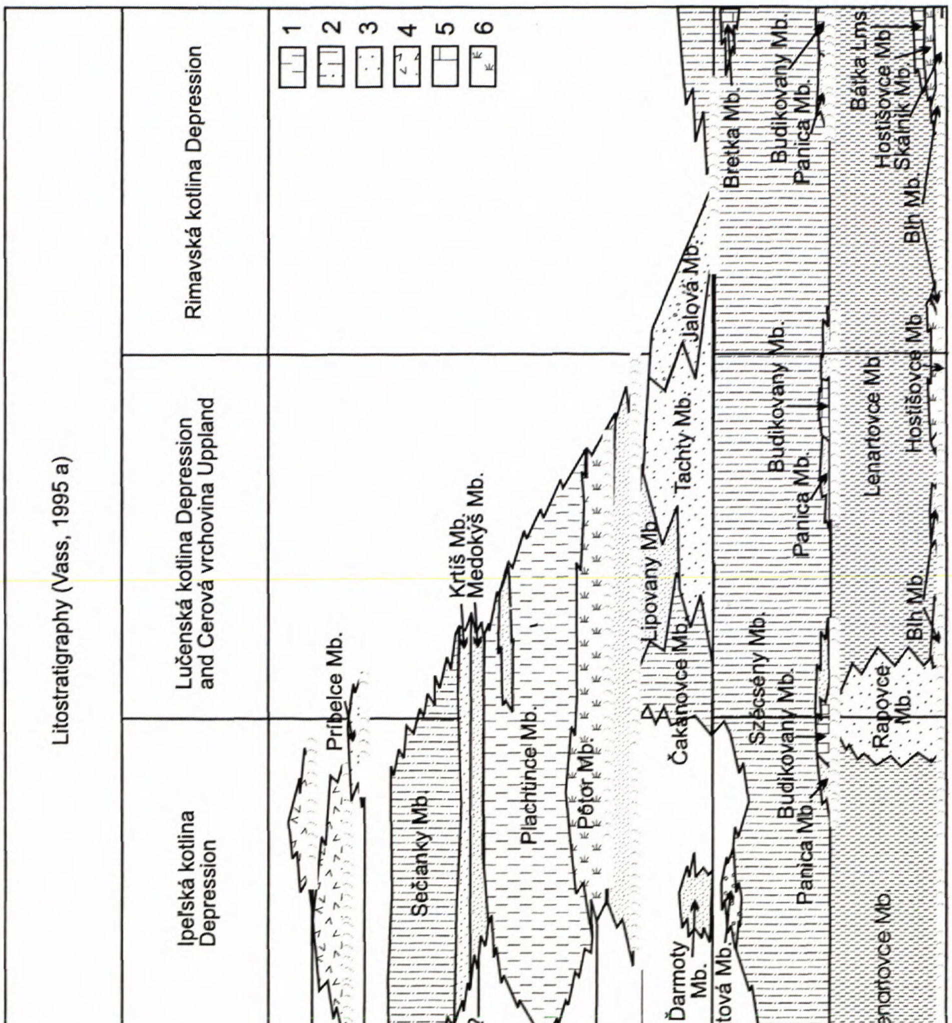

Fig. 1. A synthesis of the hitherto published litostratigraphic, biostratigraphic and radiometric data from the South Slovak depressions, tectonic events and correlation with global sea-level changes. 1 – claystones, 2 – siltstones, 3 – sandstones, 4 – volcanoclastics, 5 – limestones, 6 – fluviolacustrine and terrestrial deposits

and correlated with the Central Paratethys stages. Marine units were correlated with standard planktonic foraminiferal and calcareous nannoplankton zonation (Fig. 1 based on data from the Vass et al., 1979, 1983, 1986, 1989, 1992).

Three important tectonic events were distinguished for the South Slovak depressions (Vass et al., 1993; Márton et al., 1995; Vass, 1995):

(1) 19-20 Ma - escape controlled by left-lateral strike-slip along the Plešivec-Rapovce Fault (several tens of kms);

(2) 18-17 Ma - first phase of rotation: CCW rotation by 50°;

(3) 16-15.5 Ma - second phase of rotation: CCW rotation by 30°.

2. Methods

Foraminifers were separated from the washing residuum using standard methods. Fraction > 63 μm was analysed. 200-300 specimens were used for quantitative analysis. Weight of the washed rock sample and of the washed residuum were recorded.

Calcareous nannoplankton was analysed using standard method in light microscope.

The following methods were first applied in the South Slovak depressions:

1. Biostratigraphy based on the correlation of LAD and FAD of biostratigraphically significant species instead of correlation with standard biozones. Planktonic foraminiferal species and calcareous nannoplankton species were discussed. Well recognizable horizons were selected for precise microbiostratigraphic correlation.

2. Taphonomical analysis. Suspension-transported, bedload-transported and indigenous tests were recognized using analysis of size-sorting of tests, their abrasion and

corrosion and coexistence of species with differnet ecological requirements in assemblages (Holcová 1996a). Paleoecology can be precised and interpreted separately for source areas and areas of deposition. (Fig. 2)

3. Analysis of reworked species. Such species can be recognized if their stratigraphical ranges differ from the those of species from autochthonous assemblages. Occurrences of reworked microfossils were used for the interpretation of source material for sediments (Fig. 3).

4. Multivariate statistics was aplied in paleogeography (Šutovská et al., 1993; Holcová and Maslowská, 1999).

5. Paleoecological synthesis as an indicator of tectonic activity. Paleoecological interpretations for isochronous samples were compared. Significant differences in paleoenvironment interpreted for neighbouring samples may indicate horizontal displacement along strike-slip faults.

6. Analysis of cyclicity in foraminiferal and calcareous nannoplankton assemblages can be used in detailed stratigraphy (Holcová, 1999).

Sedimentary history of the South Slovak depressions was reconstrued for the time interval defined by prominent biostratigraphic events (LADs and FADs of calcareous nannoplankton and planktonic foraminiferal species). The lithostratigraphic units were correlated with these time intervals, and a synthesis of paleoecological reconstruction was made for them.

4. Results

4.1. Important biostratigraphic events

4.1.1. LAD of *Paraglobigerina opima opima*

LAD of *Paraglobigerina opima opima* is the first significant event in the South Slovak depressions. Berrgren et al. (1995) dated this event to 27.1 Ma (= approximately Kiscellian/Egerian boundary sensu Rögl, 1998), Cicha et al. (1998) correlated it with the Lower Egerian. In the South Slovak depressions, this event is connected with a change in the character of foraminiferal assemblages: large-size and diversified older assemblages with *Paraglobigerina opima opima* were substituted by small-size, low-diversified assemblages composed mainly of small-sized globigerinas. A decreasing diversity of planktonic foraminifers in this time interval was recorded also in the Pacific Ocean (Srinivasan and Kennett, 1983).

In the analysed material, this event can be corellated with the lithological change from the Lénartovce Mb. to the Szécsény Mb or appears in the lowermost part of the Szécsény Mb.

4.1.2. FAD of *Helicosphaera kamptneri*

This event was recorded in two boreholes as a marked event in the lower part of the Szécsény Mb. Perch-Nielsen (1985) described its FAD around the NN 1, NN 2 zones. Savitska (unpublished data) reported this event at the NN 1/NN 2 boundary from the Ukraine Carpathians. In the South Slovak depressions, this event needs verification using a higher number of sections.

4.1.3. LAD of *Reticulofenestra bisecta*

LO of *Reticulofenestra bisecta* is used to approximate the NP 25/NN 1 boundary (Berrgren et al., 1995; 23.9 Ma, Rio et al., 1990 for the Indian Ocean). In the Mediterranen, this event was recorded in the lower part of NN 1 Zone (Fornaciari and Rio, 1996). In the Central Paratethys, it was reported from younger sediments (NN1/NN2 boundary, Savitska, unpublished data). In the study area, this species was observed continuously up to the level with *Discoaster druggi* and *Globigerinoides trilobus*. As many reworked Oligocene nannoliths occur at this level (*Cyclicargolithus abisectus, Helicosphaera recta, Discolithina latelliptica,* etc.), reworking of *Reticulofenestra bisecta* is also expected at this time level. No criteria were found for the recognition of its reworking. Therefore, the LAD of *Reticulofenestra bisecta* cannot be used as a good biostratigraphic marker.

4.1.4. FADs of *Globigerinoides primordius* and *Reticulofenestra pseudoumbilica*

In the study area, FAD of *Reticulofenestra pseudoumbilica* is a very common event, while *Globigerinoides primordius* is rare. These events were mentioned also in the manuscripts of Tuba in Vass et al. (1986) and Báldi in Vass et al. (1986).

Berrgren et al. (1995) dated the FAD of *Globigerinoides primordius* to 26.7 Ma. In the Central Paratethys, the FAD of *Globigerinoides primordius* is placed to the lowermost Egerian (Cicha et al., 1971; Cicha et al.,1975; Horváth, 1983; Kucinsky, 1984; Gruzman, 1983; Cicha et al., 1998) while the FAD of *Reticulofenestra pseudoumbilica* appeared at the NN1/NN2 boundary (Marineatu, 1993). In the Atlantic Ocean near Madeira, Howe and Sblendorio-Levy (1998) described the FAD of *Reticulofenestra pseudoumbilica* (> 7 µm) in the upper part of NN 2 Zone. In the Mediterranean, the FAD of *Reticulofenestra pseudoumbilica* was described only in the Middle Miocene (NN 6 Zone; Fornaciari and Rio, 1996). This discrepancy is caused by different taxonomical concept of authors. Small-sized specimens are also determined as *R. pseudoumbilica* in the Paratethys, but only specimens larger than 11 µm are described as *R. pseudoumbilica* in the Mediterranen.

The isochroneity of the FADs of *Globigerinoides primordius* and *Reticulofenestra pseudoumbilica* is specific for the South Slovak depressions. In other basin of the Central Paratethys FAD of *Globigerinoides primordius* preceded FAD of *Reticulofenestra pseudoumbilica.*

Also the succession of the LAD of *Paraglobigerina opima opima* and FAD of *Globigerinoides primordius* in the South Slovak depressions differs from the other Central Paratethys basins. The following succesion of significant FAD and LAD of planktonic foraminifers was observed in the same Buda Basin in northern Hungary including stratotype sections Eger and Novay (Sztrákos, 1978; Horváth, 1983): 1. FAD *Globigerinella obesa*, FAD *Globigerinoides* (Egerian/Kiscellian boundary), 2. LAD *Paraglobigerina opima opima* (Lower Egerian).

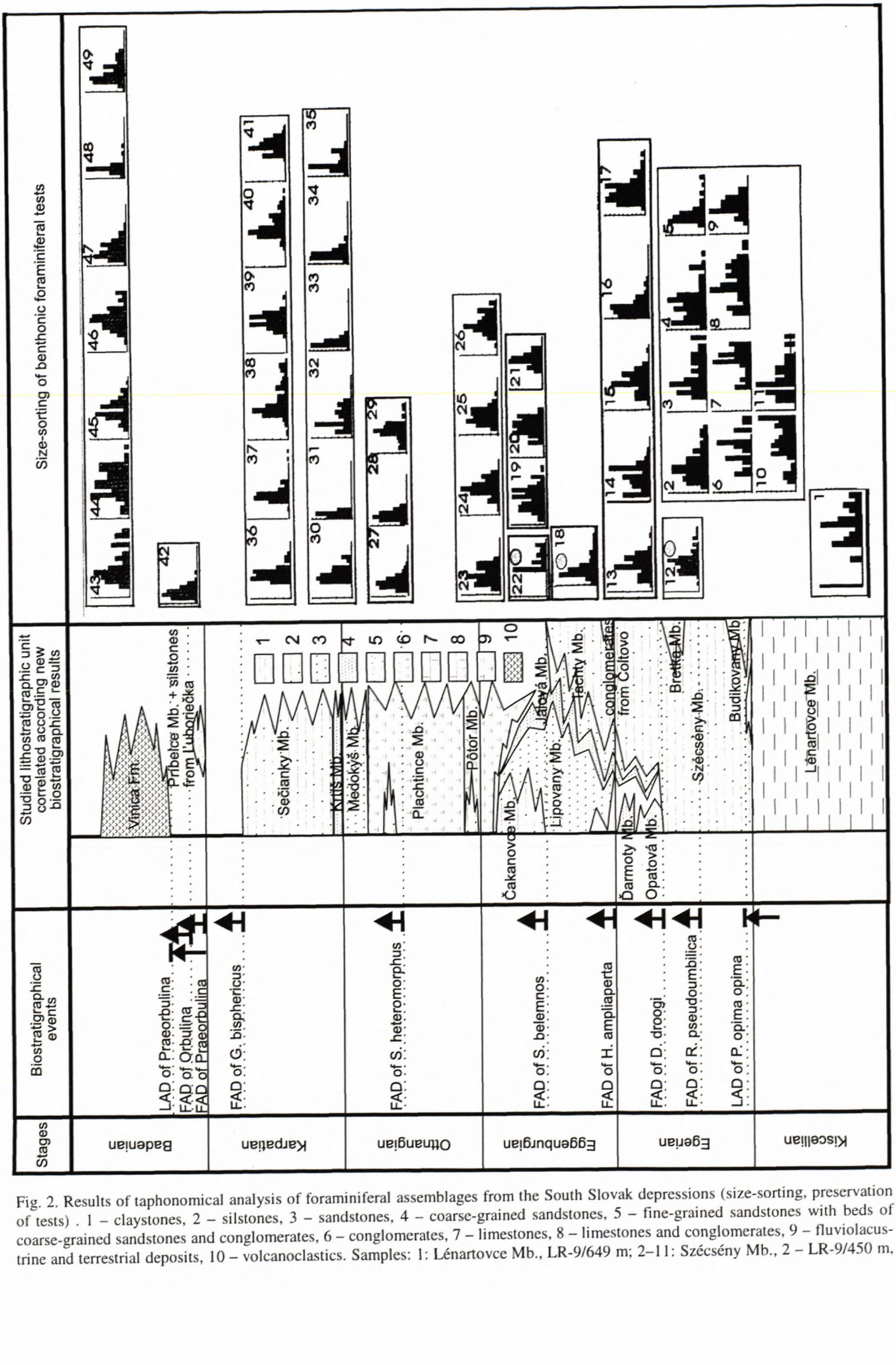

Fig. 2. Results of taphonomical analysis of foraminiferal assemblages from the South Slovak depressions (size-sorting, preservation of tests) . 1 – claystones, 2 – silstones, 3 – sandstones, 4 – coarse-grained sandstones, 5 – fine-grained sandstones with beds of coarse-grained sandstones and conglomerates, 6 – conglomerates, 7 – limestones, 8 – limestones and conglomerates, 9 – fluviolacustrine and terrestrial deposits, 10 – volcanoclastics. Samples: 1: Lénartovce Mb., LR-9/649 m; 2–11: Szécsény Mb., 2 – LR-9/450 m,

This observation agrees with the stratigraphical ranges of the species given by Cicha et al. 1998. The same succesion of these species was used in planktonic foraminiferal zonation proposed for the Central Paratethys by Cicha et al., 1975 (zone *Globorotalia opima opima - Globigerinoides*).

In the South Slovak depressions, the interval between the LAD of *Paraglobigerina opima opima* and the FAD of *Globigerinoides primordius* is characterized by low-diversified, small-sized assemblages of planktonic foraminifers. This interval was also found in northern Hungary but is shorter than in the South Slovak depressions (glauconitic sand in the lowermost Egerian). Both biostratigraphic specifics observed in the South Slovak depressions (isochroneity of the FADs of *Globigerinoides primordius* and *Reticulofenestra pseudoumbilica* and succession of the LAD of *Paraglobigerina opima opima* and FAD of *Globigerinoides primordius*) are caused by the late FAD of *Globigerinoides primordius* in the South Slovak depressions. The late penetration of *Globigerinoides primordius* (together with more diversified planktonic foraminiferal assemblages) into segments of the Buda Basin now situated in the South Slovak depressions probably resulted from tectonic activity in this period, which changed configuration of the basin and isolated this part of the Buda Basin. Precise palynspastic reconstructions of the original location of this isolated bay is impossible because all tectonic displacements have not been explained yet.

4.1.5. FADs of *Discoaster druggi* 23.2 Ma and *Helicosphaera scissura*

The FAD of *Discoaster druggi* was used for the definition of base of the NN 2 Zone and was dated on 23.2 Ma (Berggren et al. 1995). This event is well observed in the Mediterranean (Fornaciari and Rio, 1996). In the Central Paratethys, this event was mentioned from the same level from the Ukraine: NN1/NN 2 boundary.

In the South Slovak depressions, there are two practical problems in distinguishing this event: the species are rare, discoasters are often broken, and these broken specimens cannot be correctly determined.

It is very probable that the FAD of *Discoaster druggi* can be correlated with the FAD of *Helicosphaera scissura*. The latter species is relative by abundant and the events are well observable. The event of the FAD of *Helicosphaera scissura* has not been mentioned from other parts of the Central Paratethys.

4.1.6. FADs of *Helicosphaera ampliaperta* and *Globigerinoides trilobus*

These are local events, important for the Mediterranean and Central Paratethys (FAD of *Helicosphaera ampliaperta*), or only for the Central Paratethys (FAD of *Globigerinoides trilobus*). FAD of *Helicosphaera ampliaperta* was dated to aproximatelly 20 Ma from the Mediterranean (Fornaciari and Rio, 1996). From the Central Paratethys, they are described from Romania and placed within the NN 2 Zone (Marunteanu, 1992). The species appeared in the transsgresive Loiberstdorf Fm. from the Eggenburgian stratotype Loibersdorf (Holcová, in prep.).

The FAD of *Globigerinoides trilobus* was described from different stratigraphical levels in the Central Paratethys: Cicha et al. 1998 dated it to the upper Egerian, and so did Trofimovitsh (unpublished data) from the Ukraine. In Romania, this species is mentioned from the middle Egerian (Popescu, unpublished data).

4.1.7. FAD of *Sphenolithus belemnos*

The FAD of *Sphenolithus belemnos* is dated to 19.2 Ma (Berggren et al., 1995) and defined aproximately the NN 2/NN 3 boundary and strictly the CN 1/CN 2 boundary. Fornaciari and Rio (1996) dated this event to aproximately 19.1 Ma in the Mediterranean area. From the Central Paratethys, this event was described in Romania at the NN 2/NN 3 boundary (Marunteanu, unpublished data). Savitska (unpublished data) described the FAD of *Sphenolithus belemnos* from the interval of the NN 2 + NN 3 zones.

In the South Slovak depressions, the FAD of *Sphenolithus belemnos* was observed in the uppermost part of the Lipovany Mb. The specimens are small-sized but morphologically fully identical with the holotype.

4.1.8. FAD of *Sphenolithus heteromorphus*

The FAD of *Sphenolithus heteromorphus* was dated to 18.2 Ma (Berggren et al., 1995). Fornaciari and Rio (1996) mentioned only FCO of this species from the lower part of NN 4 Zone. In the Central Paratethys, Marunteanu (unpublished data) described this event from the upper part of the NN 3 Zone.

In the South Slovak depressions, this event was reported from the marine ingression in the Plachtince Mb.

3 – LR-9/200 m, 4 – LR-9/12 m, 5 – LR-10/400 m, 6 – LR-10/150 m, 7 – LR-9/75 m, 8 – Španie Pole, 9 – Jesenské, 10 – Tornaľa-Behynce, 11 – Budikovany; 12 – Bretka Mb., Bretka - stratotype of Bretka Mb.; 13–17: Opatová Mb., 13 – ČO-1/96 m, 14 – VV-12/15 m, 15 – VV-12/6 m, 16 – ČO-1/6 m, 17 – ČO-1/74 m; 18: Ďarmoty Mb., Slovenské Ďarmoty, stratotype of Ďarmoty Mb.; 19–21: Tachty Mb., 19 – EH-1/77 m, 20 – Hostice, 21 – EH-2/20 m; 22: Jalová Mb., stratotype of Jalová Mb.; 23 – 26: Lipovany Mb., Lipovany, stratotype of Lipovany Mb.; 27–29: Plachtince Mb., 27 – D-19/561 m, 28 – D-19/588 m, 29 – LKŠ-1/340 m; 30 – 35: Medokýš Mb., 30 – N-65/120 m, 31 – Malý Krtíš, stratotype of Medokýš Mb., 32 – LKŠ-1/238 m, 33 – N-91/360 m, 34 – N-91/340 m, 35 – N-91/310 m; 36–41: Sečianky Mb., 36 – LKŠ-1/187 m, 37 – LKŠ-1/145 m, 38 – LKŠ-1/85 m, 39 – LKŠ-1/26 m, 40 – N-91/230 m, 41 – N-91/215 m; 42: Príbelce Mb., Horné Príbelce, stratotype of Príbelce Mb.; 43–49: tuffs with marine fauna in Vinica Fm., 43 – Trenč, 44 – Hámor, 45 – Plášťovce, 46 – N-83/278 m, 47 – N-83/225 m, 48 – N-95/275 m, 49 – N-95/250 m. Range of test size: 0,09–0,5 mm; lenght of class in histograms: 0,03 mm.

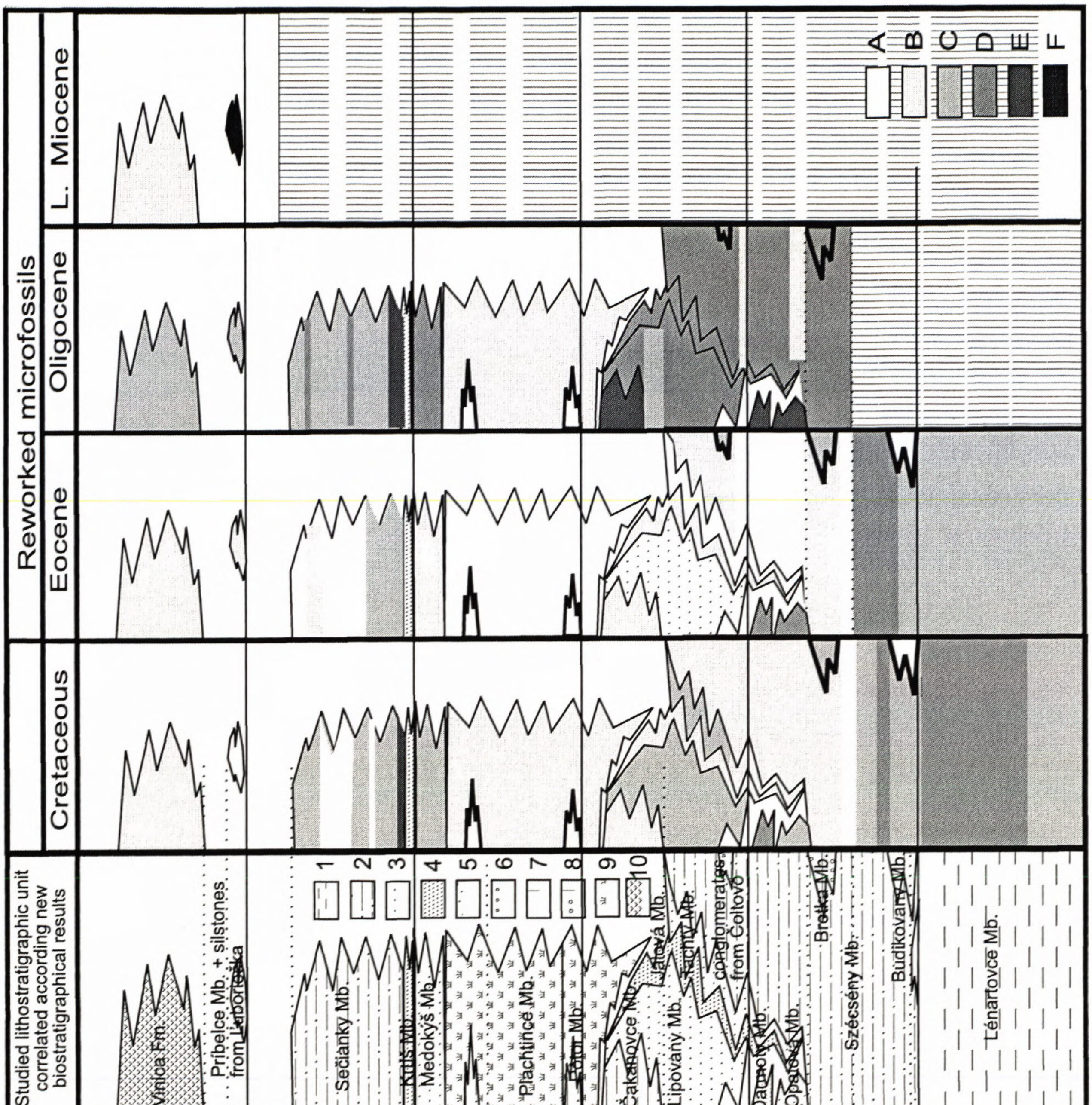

Fig. 3. Abundance and stratigraphical ranges of reworked assemblages in Oligocene and Miocene formations of the South Slovak depressions. 1 – claystones, 2 – silstones, 3 – sandstones, 4 – coarse-grained sandstones, 5 – fine-grained sandstones with beds of coarse-grained sandstones and conglomerates, 6 – conglomerates, 7 – limestones, 8 – limestones and conglomerates, 9 – fluviolacustrine and terrestrial deposits, 10 – volcanoclastics. A – F: Relative abundance of reworked species, A – 0 %, B – less than 1 %, C – 1-5 %, D – 5-10 %, E – 10–50 %, F – more than 50 %.

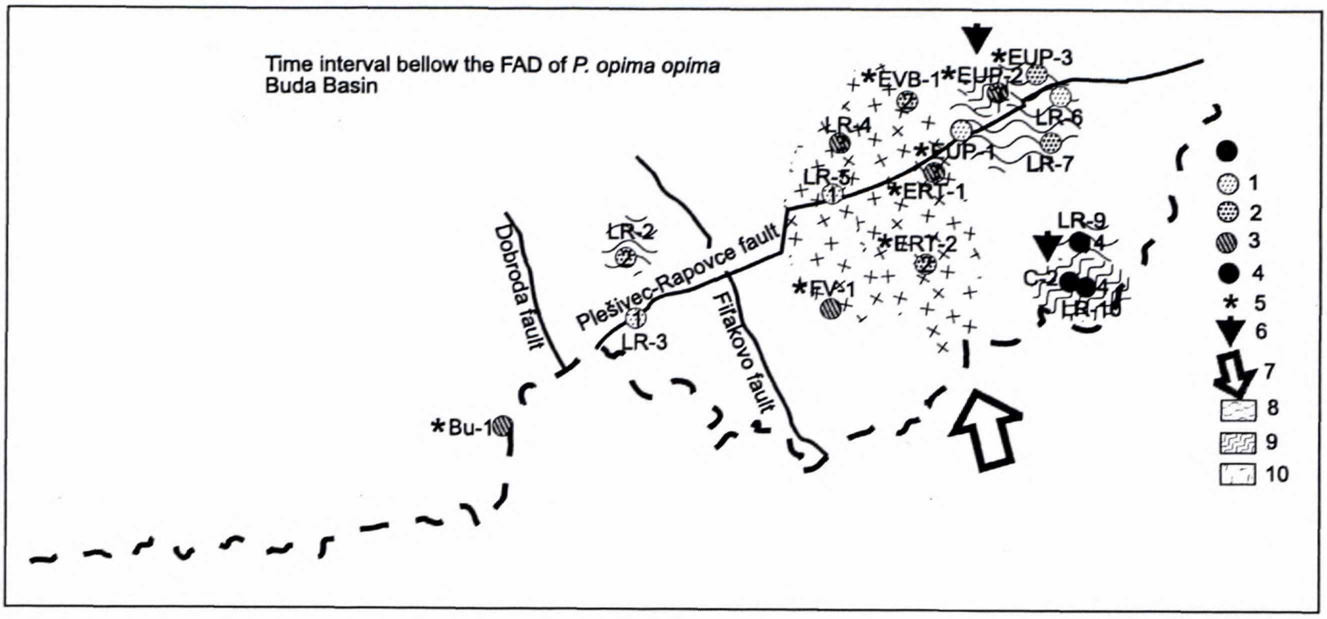

Fig. 4. Distributions of the studied foraminiferal assemblages in the South Slovak depressions in the time interval below the FAD of *P. opima opima*. 1 – littoral, 2 – upper neritic, 3 – lower neritic, 4 – low-oxic, lower neritic to upper bathyal, 5 – revised material deposited in collections of the Slovak Geological Survey, Bratislava, 6 – local depocentre, 7 – proposed marine connection with other basin, 8 – LAD of *P. opima opima* correlated with layer of coarse-grained sediments, glauconite or limestone, 9 – LAD of *P. opima opima* correlated with lithological change from claystones to siltstones, 10 – LAD of *P. opima opima* in the Lučenec Fm. Numbers 1 – 4 represent groups obtained by the Braun-Blanquet's methods.

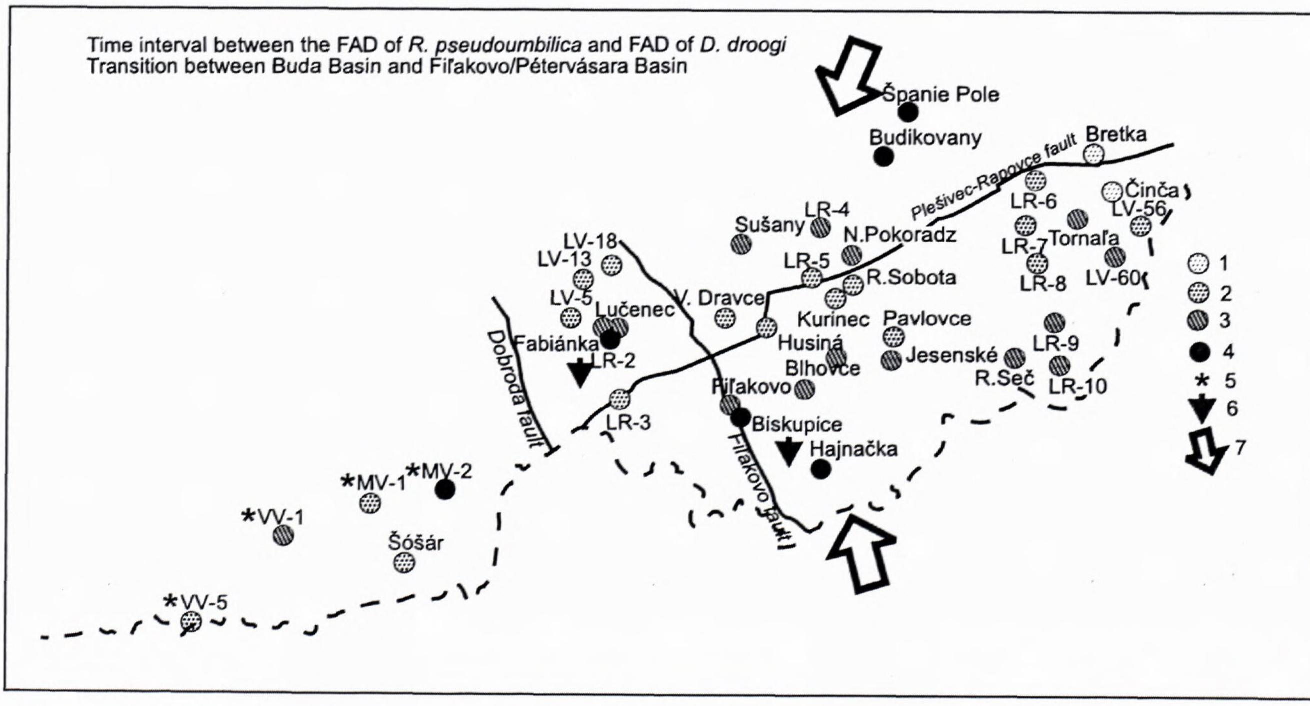

Fig. 5. Distributions of the studied foraminiferal assemblages in the South Slovak depressions in the time interval between FAD of *Reticulofenestra pseudoumbilica* and FAD of *Discoaster druggi*. 1 – littoral, 2 – upper neritic, 3 – lower neritic with low P/B-ratio, 4 – lower neritic with high P/B-ratio, 5 – revised material deposited in collections of the Slovak Geological Survey, Bratislava, 6 – local depocentre, 7 – proposed marine connection with other basin.

From the biostratigraphic point of view, a coexistence of *Sphenolithus belemnos* and *Sphenolithus heteromorphus* is mentioned. This is a short event recorded at one level in marine sediments of the Plachtince Mb. The possible coexistence of these species was discussed for different regions: common occurrence was mentioned from the Atlantic Ocean (Bukry, 1972; Takayama and Sato, 1985) and from the equatorial Pacific (Pujos, 1985). The event was not observed in the equatorial Atlantic (Olafsson, 1989), subtropical Indic Ocean (Fornaciari et al., 1990) and the Mediterranean (Fornaciari and Rio, 1996).

4.1.9. LAD of *Sphenolithus belemnos*

The LAD of *Sphenolithus belemnos* is dated to 18.3 Ma and defined by the NN 3/NN 4 boundary (Berggren et al., 1995). In the Mediterranean realm, this boundary was defined by the LCO of *Sphenolithus belemnos* (Fornaciari and Rio 1996). In the Central Paratethys, the LAD of *Sphenolithus belemnos* is correlated with NN 3/NN 4 in Romania (Marunteanu, unpublished data).

Continous marine sedimentation during the interval around LAD of *Sphenolithus belemnos* did not occur in the South Slovak depressions. The first sediments without *Sphenolithus belemnos* pertain to the Medokýš Mb.

4.1.10. FAD of *Globigerinoides bisphericus*

This event was described from the Medditerranean (Iaccarino, 1985) and dated to about 18.5 Ma in the zone with *Sphenolithus heteromorphus*. This time level can be correlated with Ottnangian in the Paratethys. The FAD of *Globigerinoides bisphericus* is a significant biostratigrafical event in the Central Paratethys but its FAD in the Paratethys is later than in the Mediterranean and correlated with the middle Karpatian (Cicha et al. 1998). FAD of *Globigerinoides bisphericus* is described from the Carpathian Foredeep (Cicha 1995), East Slovak Basin (Kováč and Zlinská 1998) in the upper part of Karpatian. The event was not observed in the South Slovak depressions.

4.1.11. LAD of *Helicosphaera ampliaperta*

This important biostratigraphic event is dated to 15.6 Ma in the world ocean (Berggren et al., 1995) and defined NN 4/NN 5 boundary. LCO (16.1 Ma) and LO (about 15.8 Ma) are distinguished in the Mediterranean (Fornaciari and Rio, 1996). This event is correlated with the NN4/NN5 boundary also in all Central Paratethys basins.

The last reliable occurrence of indigenous *Helicosphaera ampliaperta* was reported from the Karpatian Sečianky Mb. from the South Slovak depressions. The occurrence of *Helicosphaera ampliaperta* in sediments with *Praeorbulina* is questionable because reworked microfossils from the Lower Miocene prevailed in these sediments.

4.1.12. FAD of *Praeorbulina*

The FAD of *Praeorbulina* represents an important bioevent dated to 16.4 Ma in the world ocean (Berggren et al., 1995), and to about 16.2 in the Mediterranean region (Iaccarino, 1985). Cicha et al. (1998) correlated this event in the Central Paratethys with the base of the Badenian. Sporadic occurrences of *Praeorbulina* were described from the Carpathian Foredeep (Cicha, 1995) from the lowstand sediments at the Karpatian/Badenian boundary. Rögl (1998) correlated this level with the beginning of transgression in the entire circum-Mediterranean region and penetration of warm-water elements (including larger foraminifers) into higher latitudes.

Only one specimen of *Praeorbulina* was recorded in the South Slovak depressions in the sediments originally correlated with the Medokýš Mb. with prevailing reworked Lower Miocene microfossils. Mentioned very rare occurrence of *Praeorbulina* may be caused by paleoenvironment insuitable for pennetration of open marine elements (shallow-water, partly hyposaline).

4.1.13. FAD of *Orbulina*

FAD of *Orbulina* in the world ocean is dated to 15.1 Ma. Iaccarino (1985) correlated this FAD with a similar time level in the Mediterranean. Cicha et al. (1998) placed the FAD of Or*bulina* to the middle part of Lower Badenian in the Central Paratethys. Some authors (Popescu, Trofimovitsch, unpublished data) correlated this event with the Karpatian/Badenian boundary in the Central Paratethys basins in Romania and Ukrainian Carpathians.

In the Slovak Slovak Basin, *Orbulina* first appeared in the Vinica Fm.

4.1.14. LAD of *Praeorbulina*

The LAD of *Praeorbulina* is dated to 14.8 Ma in the world ocean (Berggren et al. 1995). Cicha et al. (1998) correlated this LAD with the middle part of Lower Badenian in the Central Paratethys on aproximately the same level as the FAD of *Orbulina.* Overlap of stratigraphical ranges of *Praeorbulina* and *Orbulina* was recorded most Neogene Basin in the Western Carpathians: the East Slovak Basin (Kováč and Zlinská, 1998), the Danube Basin (Zlinská et al.,1997), the Vienna Basin (Kováč and Hudáčková, 1997) and the Carpathian Foredeep.

This overlap was not observed in the South Slovak depressions. This indicates a hiathus representing this time interval.

4.2. Characteristics of time intervals defined by biostratigraphic events

Among all biostratigraphic events, the most appropriate events were choosen for the South Slovak depressions and time intervals between succesive pairs of these events were characterized.

Buda Basin

4.2.1. Time interval between the beginning of Oligocene sedimentation and LAD of *P. opima opima* (Kiscellian and lowermost Egerian)

In the South Slovak depressions, this time interval can be generally correlated with the deposition of the Lénartovce Mb. and with the Kiscellian. The age of the LAD of *P. opima opima* given by Berrgren et al. (1995), 27.1 Ma, can be well correlated with the age determined for the Kiscellian/Egerian boundary (about 27 Ma, Rögl, 1998).

Absence of older Oligocene bioevents indicates the Upper Kiscellian age of Lénartovce Mb.

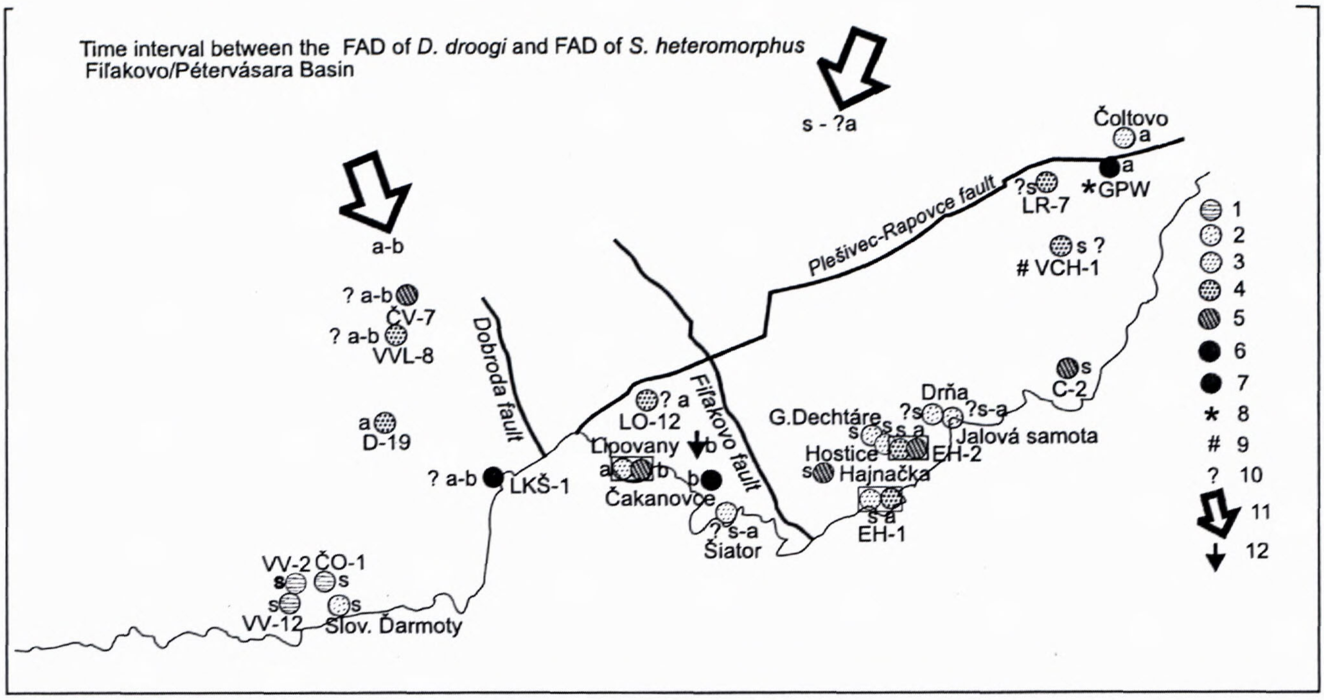

Fig. 6. Distributions of the studied foraminiferal assemblages in the South Slovak depressions in the time interval between the FAD of *Discoaster druggi* and FAD of *Sphenolithus heteromorphus*. 1 – deltaic (alternation of suspension-transported and *Ammonia*-assemblages), 2 – hyposaline, 3 – littoral, normal marine, 4 – upper neritic, 5 – lower neritic with low P/B-ratio, 6 – lower neritic with high P/B-ratio, 7 – low-oxic, 8 – revised material deposited in collections of the Slovak Geological Survey, Bratislava, 9 – biostratigraphic data from Ondrejíčková, 10 – imprecise biostratigraphic correlation, 11 – proposed marine connection with other basin, s – time interval between the FAD of *Discoaster druggi* and FAD of *Helicosphaera ampliaperta,* a – interval between the FAD of *Helicopshaera ampliaperta* and FAD of *Sphenolithus belemnos*, b – interval between the FAD of *Sphenolithus belemnos* and FAD of *S. heteromorphus*.

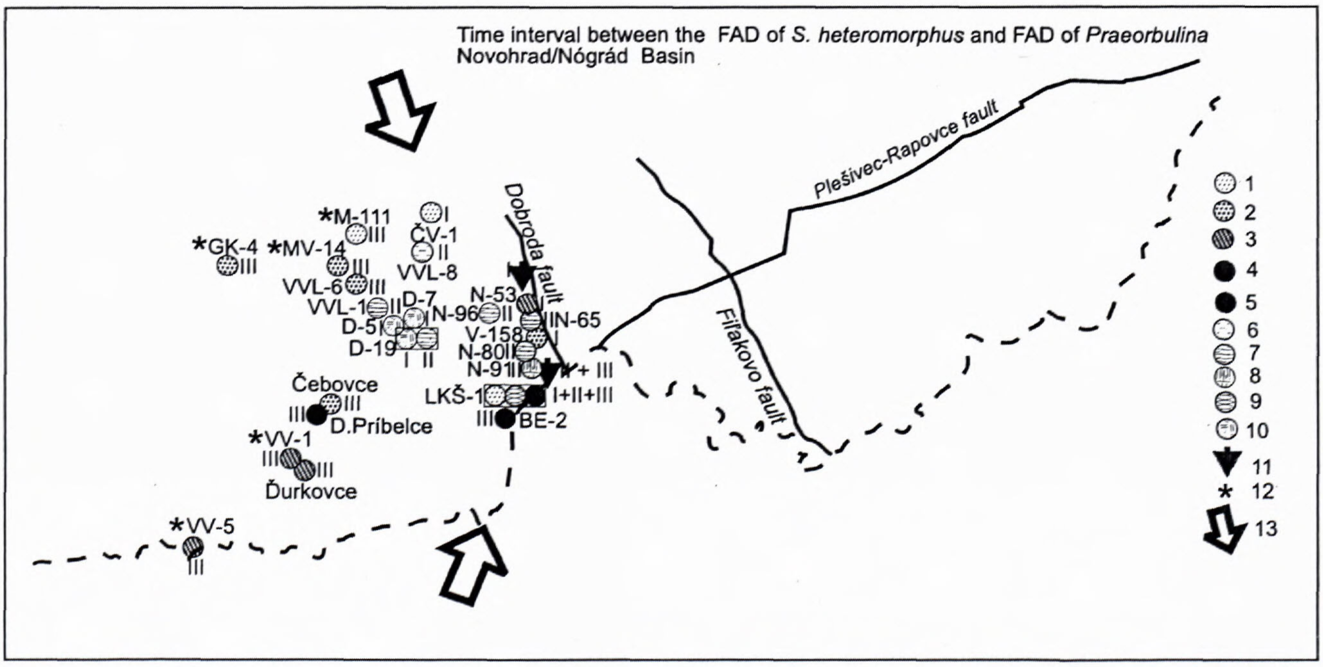

Fig. 7. Distributions of the studied foraminiferal assemblages in the South Slovak depressions in the time interval between the FAD of *Sphenolithus heteromorphus* and FAD of *Praeorbulina*. 1 – littoral, 2 – upper neritic, 3 – lower neritic, 4 – bathyal, 5 – low-oxic, 6 – only suspension-transported foraminiferal tests in assemblage, 7 – suspension-transported tests + indigenous strongly hyposaline, 8 – suspension-transported tests + indigenous littoral hyposaline to normal marine, 9 – suspension-transported tests + indigenous upper neritic, 10 – upper neritic + suspension-transported planktonic foraminiferal tests, 11 – local depocentre, 12 – revised material deposited in collections of the Slovak Geological Survey, Bratislava, 13 – proposed marine connection with other basin, I – Ottnangian marine ingressions, II – sea-level cycle respresented by the Medokýš Mb. III – sea-level cycle represented by the Sečianky Mb.

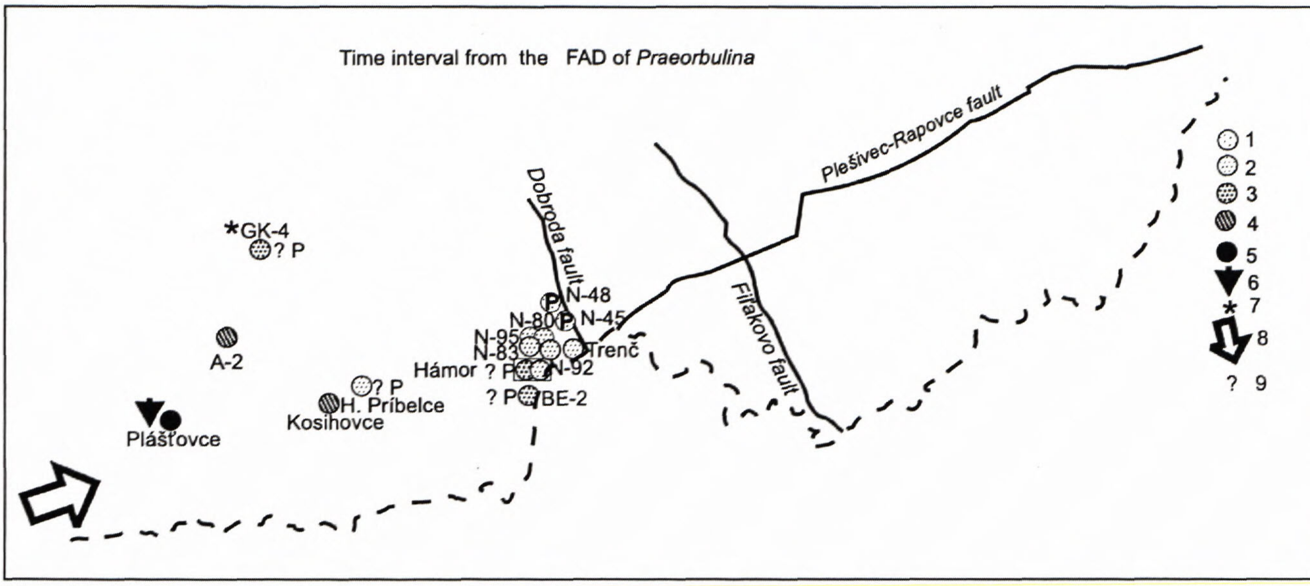

Fig. 8. Distributions of the studied foraminiferal assemblages in the South Slovak depressions in the time interval between the FAD of *Sphenolithus heteromorphus* and FAD of *Praeorbulina*. 1 – hyposaline, 2 – littoral, normal marine, 3 – upper neritic, 4 – lower neritic with low P/B-ratio, 5 – lower neritic with high P/B-ratio, 6 – local depocentre, 7 – revised material deposited in collections the Slovak Geological Survey, Bratislava, 8 – proposed marine connection with other basin, 9 – imprecise biostratigraphic correlation.

Sediments with *P. opima opima* occur sporadically only in boreholes (nine boreholes with sediments from this time interval were studied). The LAD of *P. opima opima* is connected with a well distinct lithological change from dark claystones of the Lénartovce Mb. to lighter siltstones of the Szécsény Mb. Beds with glauconite, beds of limestones or coarse-grained sediments (conglomerates) appear around the LAD. In other boreholes, a gradual change from the Lénartovce Mb. to the Szécsény Mb. was observed. Kantorová in Vass et al. (1986) described *Paraglobigerina opima opima* also from the lowermost part of the Szécsény Mb. from borehole (FV-1) with a gradual transition from the Lénartovce Mb. to the Szécsény Mb. Spatial distribution of different types of the boundary between the Lénartovce Mb. and the Szécsény Mb. is figured on Fig. 4. Different types of transitions from the Lénartovce Mb. to the Szécsény Mb. connected with the LAD of *Paraglobigerina opima opima* may indicate a more complicated tectonic displacement of the original sedimentary basin.

There are two possibilities to explain the find of *Paraglobigerina opima opima* in the Szécsény Mb.:

(1) lithological change from the Lénartovce Mb. to the Szécsény Mb. is isochronous and *Paraglobigerina opima opima* may locally survive till the lower Egerian.

(2) LAD of *Paraglobigerina opima opima* is isochronous and sections with gradual change from the Lénartovce Mb. to the Szécsény Mb. are complete. An abrupt lithological change may be connected with a short-time hiathus and the absence of the lowermost part of the Szécsény Mb. with *Paraglobigerina opima opima.* This second possibility is more probable.

Benthonic foraminiferal assemblages are characterized by high abundance and high diversity (but not as high as in Hungary) and higher P/B-ratio than in the overlying sediments (20 - 40 % as opposed to 5 - 20 %). Species composition of benthonic foraminiferal assemblages is different from that of the overlying assemblages and can be well distinguished by multivariate statistics (block clustering analysis, Šutovská et al. 1993). Assemblages are indigenous: no size-sorting, no abrasion and corrosion were observed, juveniles and adults are present.

The assemblages can be well paleoecologically interpreted. The maximum paleodepth is estimated at 500 m. Assemblages with euryoxibiont elements were recorded in the central part of the basin. The occurrence of pyrite is characteristic for these washing residua and indicates low-oxic paleoenvironment. This anoxic event is characteristic for the whole Paratethys (Rögl, 1998). In marginal parts of basin, hyposaline assemblages occur with *Elphidiella* div. sp. Hypersaline lagoonal facies was described from the Krupina Depression (Vass et al., 1979). Shallowing was observed in the uppermost part of this time interval.

Based on the character of anoxic events, three categories of Oligocene to Miocene basins in the central Paratethys were distinguished (Šutovská, 1990):

(1) those where low-oxic environment occurred in the central part of basin dominated by deposition of dark claystone. Marginal parts of the basin were characterized by hyposaline facies. This distribution of low-oxic environment required stable development, and tectonically inactive marine basins with flat bottom in the central part and weak circulation of near-bottom waters.

(2) low-oxic environment was distributed locally in different paleodepths. This type of distribution of low-oxic facies was connected with the deposition of "schlier". This is interpreted for periods of depth-diversified bottom, when low-oxic environment persisted

only in partly isolated small parts of basin for limited time periods.

(3) low-oxic environment did not develop. Periods with no low-oxic environment can be connected with period of large transgressions.

The Kiscellian anoxic event represents type (1) of this classification.

Using Brau-Blanquet methods's (Brau-Blanquet, 1964; application in micropaleontology Hilterman and Tuxen, 1974), 4 types of assemblages of benthonic foraminifers were distinguished. Their spatial distributions (as well as spatial distribution of other studied Kiscellian samples) are shown in Fig. 4. This figure gives a rough idea about the paleogeography of the South Slovak depressions during the Kiscellian: southward deepening was generally observed (from the upper neritic to the lower neritic zones, approximatelly from 50 to 500 m). Shallow-water assemblages along the SW-NE belt (Rapovce - Čierna Lúka - Teriakovce) can be parallelized with similar discrepancy in paleodepth interpretation in the Egerian (Fig. 5). The occurrence of a shallow-water assemblage in the middle of the present-day South Slovak depressions probable indicates postsedimentary displacement of NW and SE segments and it can be well paralleled with the post-Egerian escape controled by the left strike-slip along the Plešivec-Rapovce Fault (Vass et al., 1993). Different types of transitions from the Lénartovce Mb. to the Szécsény Mb. in the South Slovak depressions may indicate more complicated tectonic displacement of the original sedimentary basin along smaller ruptures.

In the calcareous nannoplankton assemblages, *Cyclicargolithus floridanus* prevailed over *Coccolithus pelagicus,* which dominated the assemblages of the overlying Szecseny Mb. Cretaceous and Eocene reworked calcareous nannofossils are present, Cretaceous prevailed in the upper part of the sections.

Based on the oscillation of foraminiferal abundance in the Lénartovce Mb. (high in its middle part, lower in the lower and upper part of the cycle), increasing abundance of reworked microfossils in its upper part and shallowing in its uppermost part, one cycle of sea-level changes can be interpreted for this unit. The correlation of local cycles with global sea-level changes during the Kiscellian and the lower Egerian is possible. Based on the ages of LAD of the *P. opima opima* and the Kiscellian/Egerian boundary, the Kiscellian cycle may be correlated with cycle TB 1.2 of global sea-level changes (Haq, 1988, 1991) in agreement with Vass (1995).

4.2.2. Time interval between LAD of *Globorotalia opima opima* and FADs of *Globigerinoides primordius* and *Reticulofenestra pseudoumbilica* (lower part of Egerian)

This interval can be correlated with the lower part of Szécseny Mb. (with the exception of the lowermost part, in some boreholes probably missing). In the studied material, sediments of this time interval occur only in boreholes. Lithological character of the lower boundary was discussed in the previous chapter. In the marginal part of the basin, this time interval probably started with Budikovany Mb. The upper boundary defined by the FADs of *G. primordius* and *R. pseudoumbilica* is not connected with any lithological change.

Planktonic foraminiferal assemblages are low-diversified with small-size, hardly determinable *Globigerina* ex gr. *praebulloides*. These assemblages are substituted by large globigerinas, globorotaliids (*Globorotalia mayeri*) and *Globigerinoides* above the FADs of *G. primordius* and *R. pseudoumbilica*.

Benthonic foraminiferal assemblages are diversified and abundant, values of diversity and abundance are correlable with the Kiscellian ones in the lower part of the interval, decrease in the upper part of the interval. Size sorting of foraminiferal tests is polymodal (Fig. 2) which indicates indigenous tests.

Assemblages are lower neritic (paleodepth can be estimated at 50 - 200 m), stenohaline, predominantly well aerated. Euryoxibiont taxa (bolivinas, uvigerinas, praeglobobuliminas) dominated in assemblages in short time intervals in different depth zones of the basin (type (2) of distribution of euryoxibiont assemblages from the previous chapter). Significant depth changes are not interpretable from the species compositions of assemblages.

Lateral changes of foraminiferal assemblages reflect higher diversification of paleoenvironment at the bottom of the basin in comparison with the Kiscellian. A detailed basin geometry was not reconstructed for this interval because sediments of this interval can be reliably distinguished in only seven boreholes. Similarity of general basin configuration (depocentre, marginal part of basin) with the Kiscellian one is supposed.

Calcareous nannoplankton assemblages are dominated by *Coccolithus pelagicus*. The abundance of nannoplankton is lower than that in the Kiscellian. Reworked Cretaceous and Eocene species are not very abundant (5 - 10 %) and reach peak abundance in the middle part of the interval.

In the marginal part of basin this interval started with sedimentation of bioclastic limestones of the Budikovany Mb. The Member is dated by large foraminifers (*Miogypsina formosensis*) to the uppermost Oligocene (Vaňová in Báldi and Seneš, 1975). Foraminifers are not so abundant and diversified as in the Szécseny Mb. Benthonic foraminiferal assemblages are dominated by cibicidoids. Cibicidoids in this interval are interpreted as shallow-water assemblages (Šutovská, 1991). Size-sorting of tests shows mixed indigenous and bedload-transported assemblages (Fig. 2). Calcareous nannoplankton is rare, the assemblages are dominated by *Coccolithus pelagicus*. Among biostratigraphically important species, *Cyclicargolithus abisectus* and *Reticulofenestra bisecta* are present. No reworked microfossils were found which characterizes transsgressive sediments.

Changes in quantitative characteristics (foraminiferal abundance, relative abundance of reworked species) may indicate cycles of sea-level changes correlable with this time interval. Correlation with global sea-level changes during the Egerian is questionable. For the South Slovak depressions, only two indistinct cycles can be defined during this interval (27.5 - 20. 5 Ma) whereas three global cycles of sea level changes (TB 1.3. - TB 1.5.) are distinguished by Haq (1988, 1991). This discrepancy is probable caused by influence of tectonic activity also reflected in the rebuilding of basin geometry during the Upper Egerian. Three cycles of sea-level changes can be observed in basins where *Globigerinoides primordius* penetrated earlier (for detailed discussion see Chapter 4.1.4.) because the FAD of *Globigerinoides primordius* can be well correlated with the base of TB 1.3. cycle (26.7 Ma versus 26.5 Ma).

Transition between Buda Basin and Fiľakovo/Pétervásara Basin

4.2.3. Interval between FADs of *Reticulofenestra pseudoumbilica* and *Globigerinoides primordius* and FADs of *Discoaster druggi* and *Helicosphaera scissura* (middle part of Egerian)

The middle part of the Szesceny Mb. was deposited predominantly during this time interval. The uppermost part of Szecseny Mb. from most of area of the South Slovak depressions was eroded and sediments of this time interval are preserved only in areas where the overlying sediments are present. No lithological changes were recorded around the FADs of *Reticulofenestrà pseudoumbilica* and *Globigerinoides primordius*. Also the changes in benthonic foraminiferal assemblages are small. Assemblages are diversiefied, tests are abundant and assemblages are composed of indigenous tests. Cluster analysis of benthonic foraminiferal assemblages from the eastern part of the basin showed some changes in species composition around these FADs (Šutovská, 1987). This is mainly caused by the disappearance of agglutinated species and increase in the relative abundance of cibicidoids (especially heterolepas). This may be a consequence of shallowing in this part of the basin. Similarly to the older interval, foraminiferal assemblages indicate lower neritic, stenohaline, predominantly well aerated environment. Distribution of euryoxibiont taxa also represents type (2) described in Chapter 4.2.1. Depth changes during this time interval cannot be inferred from species composition of the assemblages.

The most marked changes was observed in the planktonic foraminiferal assemblages above the FADs of *G. primordius* and *R. pseudoumbilica*. Assemblages composed of small-sized globigerinas are substituted by large globigerinas, globorotaliids (*Globorotalia mayeri*) and *Globigerinoides*. This indicates penetration of new faunas caused by opening of a new sea-way. This may indicate together with the increase in abundance of foraminiferal and calcareous nannoplankton and the decrease in the number of reworked nannoliths, transsgressive tract of a new cycle of sea-level changes. This transgression was described by Báldi (1986) from Hungary and is correlated with the Oligocene/Miocene boundary. No reliable biostratigraphic criterion for the correlation of FADs of *G. primordius* and *R. pseudoumbilica* with the Oligocene/Miocene boundary in the South Slovak depressions was found. Penetration of new planktonic foraminifers coincides with the period of broad connection of Indian Ocean and the Paratethys sea accompanied by penetration of numerous warm-water immigrants (Rögl, 1998).

Calcareous nannoplankton assemblages do not change relative to the assemblages from the overlying sediments with the exception of the appearance of *Reticulofenestra pseudoumbilica*. The absence of reworked species in the lower part of this horizon is notable.

During this time interval, configuration of the basin started to change (Fig. 5). This is probably a consequence of tectonic events described around the Egerian/ Eggenburgian boundary (Vass et al., 1993; Márton et al., 1995). Foraminiferal assemblages indicating the deepest paleoenvironment (lower neritic to ?upper bathyal) were described from the present NE margin of the South Slovak depressions (Španie Pole, Budikovany, Sušany). The distribution of these lower neritic assemblages agree aproximately coincides with the distribution of the Budikovany Mb., which represents littoral facies of marine basin in the lower Egerian. This probably indicates opening of a sea-way between the South Slovakia and flysh basin in the East Slovakia.

Similarly to the Kiscellian, shallow-water assemblages (upper neritic) are present in a SW-NE-trending zone (Rapovce - Čierna Lúka - Rimavská Sobota - Rašice) in the central part of the present distribution of the Upper Egerian sediments. This probably indicates postsedimentary displacement of NW and SE segments, which can be well paralleled with the post-Egerian escape controlled by the left-lateral strike-slip along the Plešivec-Rapovce Fault (Vass et al., 1993).

Changes in basin geometry may be recorded also in the shift of depocentres. Depocentres in the SE segments shifted from the eastern part of basin (Chanava) to the west (Fiľakovo, Hajnačka), in the NW segment from the surroundings of Polina and Valice (EUP-2, EUP-3) to the surroundings of Lučenec (LR-2).

This interval probably terminated the sedimentation of the Bretka Mb. distributed in the eastern part of the South Slovak depressions. The Bretka Mb. is well dated by large foraminifers. *Miogypsina gunteri* and *Lepidocyclina morgani* are present here (Váňová in Báldi and Seneš, 1975), indicating Neogene (Aquitane) age of the Bretka Mb. Foraminiferal assemblages are similar to those from the Budikovany Mb.: cibicidoids also prevail here. This is probably caused by similar paleoenvironments during the deposition of both units.

Calcareous nannoplankton assemblages are dominated by *Coccolithus pelagicus*. *Reticulofenestra pseudoumbilica* is common. Many reworked calcareous nannoplankton species indicate regressive character of the Member (contrary to the Budikovany Mb. with no reworked species).

Recording of broken specimens probably pertaining to *Discoaster druggi* may be important for biostratigraphic correlation of Bretka Mb. Confirmation of this find, may change the biostratigraphic correlation of this Member.

Fiľakovo/Pétervására Basin

4.2.4. Interval between FADs of *Discoaster druggi* and *Helicosphaera scissura* and FAD of *Helicosphaera ampliaperta* (upper part of Egerian)

Sediments of this interval were partly correlated with the Eggenburgian because the Egerian/Eggenburgian boundary was correlated with the boundary of NN 1/NN 2 zones (Lehotayová, 1984). They are recorded only in isolated occurrences, and a detailed reconstruction of basin configuration during this interval is impossible (Fig. 6). In spite of this, diversification of sedimentary environment is recorded. A general shallowing of the basin is observed, which may be connected with the diversification of marginal facies characteristic for this interval. Configuration of basin the very probable correspond to the basin geometry in the previous interval. Szecseny Mb. was deposited in the central part of the basin. The interval with *Discoaster druggi* and *Helicosphaera scissura* was found in the southern part of the South Slovak depressions: in the suroundings of Fiľakovo and Hostice, where it is overlain by Eggenburgian sediments and thus being "preserved" against denudation. Sediments of this interval can be well observed in the marginal facies in the western part of the basin: Opatovce Mb. and Ďarmoty Mb. were deposited during this time interval. The time equivalent of this marginal facies in the eastern part of Basin may be Bretka Mb. if finding of *Discoaster druggi* will be confirmed (for detailed characteristics of the Bretka Mb. see previous chapter). The Opatovce Mb. and Ďarmoty Mb. were deposited in the shallow-water and hyposaline paleoenvironment. The abundance of foraminifers is low, which, together with many reworked species and shallow-water character of the assemblages, characterizes low stand deposits. Open marine microfossils occur in both units, which indicates a good comunication with open sea.

Opatovce Mb. is represented by deltaic-facies sediments (Holcová-Šutovská et al., 1993). The assemblages are composed of indigenous and suspension-transported foraminiferal tests, which is typical for deltaic deposits. Indigenous assemblages are dominated by *Ammonia* and *Porosononion*. Open marine benthonic foraminifers are present and planktonic foraminifers are abundant in suspension-transported assemblages.

The Ďarmoty Mb. is characterized by the presence of indigenous shallow-water and hyposaline assemblages of benthonic foraminifers dominated by *Ammonia*. The occurrence of planktonic foraminifers at some levels indicates a good communication with open sea. Benthonic assemblages are more diversified than those from the Opatovce Mb. It can mirror the higher salinity during deposition of the Ďarmoty Mb. Finds of genus *Monspeliensina* are significant for the paleogeographical reconstruction. The genus appeared in the Rhône Basin during the Aquitane (Glaçon and Lys, 1968; Anglada and Magne, 1969) and is also known from the Ottnangian and Karpatian of the Central Paratethys (Holcová, 1996b). Sea-way from the Rhône Basin to the Central Paratethys across the Western Paratetys was closed during the Aquitane and the lower part of the Burdigalian, biostratigraphically defined by NN 2 Zone (Schoepfer and Berger, 1989). The exact time and sea-way penetration of *Monspeliensina* from the Rhône Basin to the Central Paratethys during the lowermost Miocene is therefore unknown. *Monspeliensina* may have come from the Mediterranean through the Slovenian corridor opened during the Early Aquitanian (Rögl and Steininger, 1983). Presence of *Monspeliensina* in the Ďarmoty Mb. in comparison with its absence in Opatovce Mb. may reflect fact that Opatovce Mb. is older than Ďarmoty Mb.

Sedimentation of the Tachty Mb started during this time interval. It represents the southern marginal facies of the basin. Pétervására Sandstone is the Hungarian equivalent of the Fiľakovo Member. Sztanó (1995) dated the beggining of their deposition also to the boundary of NN 1/NN 2 zones. The Tachty Mb. indicates local shallowing in marginal parts of the marine basin, and its base cannot be isochronous. On the basis of a detailed sedimentological analysis, Sztanó (1995) described lower aggradation and upper progradation units of the Pétervására Sandstone. The analysed material from the South Slovak depressions does not allow to distinguish this transgressive-regressive cycle, and sediments of this time interval have the character of low stand deposits (shallow-water, with many reworked species, indigenous microfossils are rare).

3. 2. 6. Time interval between FAD of *Helicosphaera ampliaperta* and FAD of *Sphenolithus belemnos* (lower part of Eggenburgian)

During this time interval, diversification of the facies continued. In spite of this, low-oxic environment was not recorded, which indicates a period of good aeration of whole basin. Changes in basin geometry may be expected. In the eastern part of the South Slovak depressions, where this interval preceded the eventual emergence and, only denudation relicts of sediments of this time interval are preserved. Only one locality from this time interval (Gemerská Panica in the NE part of the Rimavská kotlina Depression) has been reliably described from the Szecseny Mb. (Halásová et al., 1996). In the diversified benthonic foraminiferal assemblages, agglutinated taxa prevail (*Bathysiphon, Cyclammina, Haplophragmoides*). The high P/B-ratio (65 %) shows a trend of increase of this value from the lower Egerian to Eggenburgian in the Szecseny schlier. This may be caused mainly be good communication with open sea. *Globigerinoides trilobus* occurs in the planktonic foraminiferal assemblages. Assemblages are well size-sorted, indigenous.

Conglomerates isochronous with the Bretka Member were described from the Čoltovo area (Vass et al., 1989). Foraminifers do not occur in these conglomerates, but the find of *Helicosphaera ampliaperta* among calcareous nannoplankton is important for the determination of the age of these conglomerates, which can be well paralleled with the Eggenburgian. Therefore, they are younger than the Bretka Mb. but indicate similar distribution of marine marginal facies in the Lower Egerian and Eggenburgian

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in this part of the South Slovak depressions. Many Cretaceous to Oligocene reworked species occur in the calcareous nannoplankton assemblages. Communication of the South Slovak depressions with the East Slovak Basin is questionable during this time interval. *Helicosphaera ampliaperta* hase not been found in the East Slovak Basin (Prešov Mb.), but in the East Slovak Basin, the stratigraphical level with *Helicosphaera ampliaperta* may be preserved only in rare denudational relicts, or completly eroded during the long-lasting emergence.

Another lithofacies is represented by the Tachty Mb. which gradually developed from the Szecseny Mb. Foraminiferal assemblages are rare in the Tachty Mb. They contain predominantly shallow-water, hyposaline species (ammonias dominate) with cibicidoids in deeper parts (suroundings of Hostice). Size-sorting of tests (Fig. 2) and abrasion of larger tests indicate mixing of indigenous tests with tests transported in bedload. Calcareous nannoplankton assemblages are generally very rare and low-diversified with dominance of *Coccolithus pelagicus* with the exception of the assemblages from the Tachty Mb. near the village of Hostice. Reticulofenestras prevail and biostratigraphically significant species *Helicosphaera ampliaperta, Discoaster druggi* occur in the diversified assemblages. The occurrence of morphotype of *Helicosphaera ampliaperta* with large terminal flange may be significant for the paleogeographical reconstruction. This morphotype was first figured by Lehotayová (1984, Tab. 49, Fig. 3). Large terminal flange is similar to that of specimens of *Helicospheara granulata* (with broken central area) described from the NN 2 Zone in the Atlantic Ocean by Perch-Nielsen (1977) and contradicts the description of the species *Helicosphaera ampliaperta* given e.g. by Haq (1973). Aubry (1990) similar morphotype determined like *Helicosphaera ampliaperta* figured.. While typical *Helicosphaera ampliaperta* is very rare, the above mentioned morphotype with large terminal flange is common (5-10 % of assemblages). The FAD of this morphotype may precede the FAD of *Helicosphaera ampliaperta.* The nearest occurrence of this morphotype was recorded in the Flysh Belt (upper part of the Hustopeče Mb.) (Molčíková and Straník, 1987). This morphotype may have penetrated to the South Slovak depressions from the residual flysch basin through the East Slovak Basin - South Slovak depressions sea-way but no indicators of this hypothesis exist. The area with deposition of the Tachty Mb. represents shallow part of the Lower Eggenburgian basin. To the east, the basin was deeper, the Szecseny Mb. was deposited in this deeper part of basin.

Extremely shallow-water environment is represented by the Jalová Mb. Its biostratigraphic correlation with other lithostratigraphic members of the Fiľakovo Formation (Tachty Mb., Jalová Mb., Lipovany Mb., Čakanovce Mb.) is problematic because no index microfossils were recorded. It was described as a lateral facies of the Tachty, Lipovany and Čakanovce Mbs. (Vass et al., 1992). The Jalová Mb. contains rare shallow-water and hyposaline foraminiferal fauna (*Ammonia, Elphidium, Porosononion*). The tests are large, size-sorted, corroded and abraded, which indicates transport in bedload. The Jalová Mb. may represent a heterochronous but isopic facies. Based on sedimentological analysis, this unit is interpreted as filling of the tidal channels (Vass et al., 1992).

A new basin was formed in the western part of the South Slovak Basin (Fiľakovo Fault may form its eastern boundary). This interval is represented by sedimentation of the lower part of the Lipovany Mb. It contains shallow-water benthonic foraminiferal assemblages dominated by *Ammonia parkinsonia-tepida* group. Planktonic foraminifers are rare, represented by small-sized globigerinas. Foraminiferal assemblages are indigenous, reworked species were not recorded. Calcareous nannoplankton is common to abundant. The assemblages are dominated by *Coccolithus pelagicus.* If compared with the Szecseny and Tachty Mb., typical morphotype of *Helicosphaera ampliaperta* is relatively abundant and morphotype with large flange was not recorded. Reworked species are present, being dominated by Oligocene species. Diatoms appear in some horizons. Radiometric age of tuffs from this Member is 20.5+/-0.5 Ma (Repčok in Vass et al., 1992), which is in agreement with the FAD of *Helicosphaera ampliaperta.*

This basin was connected with the Bánovce depression (Halásová et al., 1996); however, the time of opening of this connection cannot be precisely determined.

Deepening of the eastern part of basin (Szesceny Mb.), transgression of the Lipovany Mb. and transgressive character of sediments of this time interval (no low-oxic facies, very few reworked microfossils) may be correlated with the begining of TB 2.1. cycle of global sea-level changes. The possibility of correlation of local and global sea-level cycles shows a decrease in tectonic activity during this time interval. On the other hand, the influence of Upper Egerian/Eggenburgian tectonic events on local sea-level changes continued, because Eggenburgian transgression is a very significant event in other Central Paratethys basins, unlike the South Slovak depressions.

Transition between Fiľakovo/Pétervásara Basin and Novohrad/Nógrád Basin

4. 2. 7. Time interval between FAD of *Sphenolithus belemnos* and FAD of *Sphenolithus heteromorphus* (upper part of Eggenburgian, lower part of Ottnangian)

This interval is characterized by sedimentation of the upper part of the Lipovany Mb. and Čakanovce Mb. The emergence of the South Slovak depressions was associated with sedimentation of fluviolacustrine Bukovinka and Salgotarián Fms. Marine ingressions were distinguished in the Pôtor Mb. (Bukovinka Fm.) and Plachtince Mb. (upper part of Salgotarián Fm.). The time interval discussed can be correlated with the earlier ingression. *Sphenolithus belemnos* was not recorded in the eastern part of the South Slovak depressions (aproximately correlated with the area east of the Fiľakovo Fault) where the Tachty Mb. and Szecseny Mb. were deposited. This may be caused by the earlier emergence of this part of the

South Slovak depressions and/or denudation of these sediments.

Rebuilding of basin morphology from the Fiľakovo/ Pétervásara Basin to Novohrad/Nógrád Basin was gradualy finished during this interval. The distribution of shallow-water and deeper-water foraminiferal assemblages from younger Ottnangian and Karpatian marine transgressions is comparable with the distribution of assemblages correlated with the first Ottnangian marine ingression (Fig. 7).

No lithological changes are observed at the level of the FAD of *Sphenolithus belemnos*. Gradual deepening of the depositional environment in the area of the Lipovany Mb. sedimentation can be observed. Stenohaline upper neritic assemblages appear among benthonic foraminiferal assemblages (cibicidoids dominated). Euryoxibiont foraminiferal assemblages with *Cassidulina* and *Bulimina* were locally recorded in the deepest part of the basin. The appearence of low-oxic environment in the deepest part of the basin indicates stabilization of marine environment. Foraminiferal assemblages are indigenous with no reworked specimens, generally small-sized but size-sorted. Calcareous nannoplankton assemblages are dominated by *Coccolithus pelagicus.* The abundance of reworked specimens slightly increases, with Oligocene redeposits prevailing.

Foraminiferal assemblages from the Čakanovce Mb. show deepening of sedimentary environment.They are the most abundant and diversified assemblages with the highest P/B-ratio in the Eggenburgian of the South Slovak depressions. Calcareous nannoplankton assemblages are similar to those from the Lipovany Mb. Horizons with diatoms in the Lipovany and Čakanovce Mbs. can be correlated with horizons containing tuffaceous material.

Isolated occurrences of Eggenburgian marine sediments from the Ipeľ Basin and from the sediments underlying the volcanics of the Krupina Plateau indicate communication between the South Slovak depressions and the Bánovce Depression (Halásová et al., 1996). The deepest, lower neritic assemblages are described from the Strháre-Trenč Graben. *Sphenolithus belemnos* was not recorded in these sediments, therefore opening of this seaway may be expected during the previous interval. On the other hand, *Sphenolithus belemnos* was reported from the whole interval of Eggenburgian sediments in the Bánovce Depression. This sea-way survived probably during the Ottnangian and Karpatian (Šutovská et al., 1993).

The maximum paleodepths and the highest abundances of indigenous foraminiferal tests in the Eggenburgian, the presence of low-oxic environment and higher abundances of reworked foraminiferal species relative to those in the overlying sediments characterize this time interval. Marine sedimentation in this basin was interrupted by the emergence in the Upper Eggenburgian/ Lower Ottnangian. This emergence may be diachronous. Terrestrial Bukovinka Fm. is correlated with the upper part of the Eggenburgian. Radiometric ages determined in this formation (20.1 +/-0.3 Ma: Repčok, 1987; 19.7+/-0.2 Ma: Kantor et al., 1988 in Vass et al., 1992) enable to correlate it with the lower part of the Eggenburgian. They are older than the FADs of *Sphenolithus belemnos* occuring in the marine Eggenburgian sediments. If these radiometric ages are correct, they may indicate diachronous emergence of the South Slovak depressions. The marine ingressions were described from this formation (Pôtor Mb.; Škvarka et aol., 1991). The Bukovinka Fm. is covered by the coal-bearing Salgotarjan Fm. Cretaceous redeposited nannofloras occur rarely in these fluviolacustrine sediments. Other ingression can be correlated with this time interval (Plachtince Mb.). For more details on those ingressions, see below.

Novohrad/Nógrád Basin

4. 2. 8. Time interval between FAD of *Sphenolithus heteromorphus* and FAD of *Praeorbulina* (upper part of Ottnangian, Karpatian)

This interval is characterized by thick sequences of marine sediments which cannot be divided by biostratigraphically significant bioevents. In the upper part of this interval, the FAD of *Globigerinoides bisphericus* represents a significant bioevent in the Paratethys basins (Cicha et al., 1998). This event was not recorded in the South Slovak depressions which can be explained by: (1) the emergence of the area during this time interval, (2) denudation of sediments of this time interval, (3) isolation of the basin during the upper part of the Karpatian; *Globigerinoides bisphericus* could not penetrate to the South Slovak depressions. The second possibility is the most probable because the study of smectite from the underlying Plachtince Mb. (Vass and Šucha, 1994) showed that the original thickness of the Modrý Kameň Fm. (Upper Ottnangian, Karpatian) was 1000 m in contrast with the present-day maximum thickness of about 400 m.

The following cycles of sea-level changes can be distinguished in the South Slovak depressions:

(1) Ottnangian marine ingression in the Pôtor and Plachtince Mb. These ingressions were mentioned by Kúšiková in Klubert (1984), Vass et al. (1987) and Škvarka et al. (1991). These finds motivated a revision of marine Ottnangian sediments (Šutovská, 1993). Two marine ingressions can be distinguished: the older in the Pôtor Mb. and the younger one in the Plachtince Mb. Foraminiferal assemblages are similar in both ingressions. Cibicidoids prevailed, assemblages in marginal parts of the basin (western part) also contained ammonias. In the deepest part of the basin (eastern part), lenticulinas are dominant and uvigerinas are present. Planktonic foraminifers are abundant in some samples, their tests are size-sorted and probably suspension-transported.

Calcareous nannoplankton assemblages are also similar in both ingressions, dominated by *Coccolithus pelagicus.* Rare specimens of *Sphenolithus belemnos* occurr in both ingressions. An assemblage with common *Sphenolithus belemnos* and small-sized *Sphenolithus heteromorphus* was observed at one locality (D-19 borehole) correlated with the upper ingression. Reworked species were recognized in assemblages, which agrees with the transgressive character of these strata.

Basin configuration equals to the configuration during the upper Eggenburgian transgresion (Fig. 6): the deepest part of the basin was situated at the southeastern margin of the present-day distribution of marine Ottnangian sediments. It reflects influence of structure of the Dačov Lom graben (Vass et al., 1979) during the Eggenburgian and Ottnangian. The eastern continuation of the marine basin was probable transected by the Dobroda fault (Vass et al., 1992). In the South Slovak depressions, Ottnangian marine ingression penetrated more westward in comparison with the area of Eggenburgian marine basins.

It is supposed that the marine ingression penetreted to the South Slovak depressions from the SW (Várpalota area, Kókay 1991) via the newly opened "Trans-Tethyan Trench Corridor" (Rögl, 1998 dated the opening of this corridor to the Karpatian). Communication with the Bánovce depression is questionable. Also communication with hyposaline Ottnangian sediments from the Bórsód basin in Hungary (Bohn-Havas, 1983) cannot be clearly documented. This interval can be correlated with the low-stand of global sea-level cycle TB 2.1. as is evident from the lowstand character of the Ottnangian deposits in the Bánovce Depression (low-oxic facies, decrease in salinity). It is probable that the sea-ways between the South Slovak depressions and the Bánovce Depression were closed during this low-stand.

(2) Sedimentation of Medokýš Mb. which was paralelled with the "*Rzehakia* (*Oncophora*) Beds".

The Medokýš Mb. is characterized by high abundances of foraminiferal tests of stenohaline open marine species. In this, the Medokýš Mb. differs from the "*Rzehakia* (*Oncophora*) Beds" in other areas. They were first described by Kantorová et al. (1968) and recently by Holcová (1996a, 1999, in print) and Holcová and Maslowská (1999). Kantorová et al. (1968) assumed the transport of foraminiferal tests of stenohaline foraminiferal species to a hyposaline basin (with hyposaline molluscs *Rzehakia)* by storm waves from an unknown open sea to a brackish basin in the area of the present-day South Slovak depressions. A detailed taphonomical study (Holcová, 1996a) confirmed and specified the previous interpretation. The study also enabled to distinguish indigenous foraminiferal tests. For the interpretation of paleodepth, three types of assemblages are significant: (1) assemblages with stenohaline, upper neritic indigenous species, (2) assemblages with indigenous hyposaline, littoral species, (3) assemblages without indigenous species. According to their distribution, the depocentre can be interpreted at the SE margin of the present-day distribution of sediments, similarly to the Eggenburgian and Ottnangian. Calcareous nannoplankton assemblages are also present. Nannoliths are common in the deepest part of basin and occur in all analysed samples. *Coccolithus pelagicus* prevailed in the assemblages. Cretaceous, Eocene and Oligocene reworked species were recorded.

Opinions on the age of the Medokýš Mb. are controversial. Correlation of the "*Rzehakia* (*Oncophora*) Beds" with the Upper Ottnangian prevails in most Paratethys basins where the „Beds" represent a regressive phase of the Eggenburgian-Ottnangian cycle. In the Pannonian Basin, the "*Rzehakia (Oncophora)* Beds" seem to be in a transgressive position, overlying the continental Ottnangian sediments. Therefore, the "Beds" are considered younger (Karpatian) than the "*Rzehakia (Oncophora)* Beds" in other basins. Occurrences of *Uvigerina graciliformis* Papp et Turnovski and *Sphenolithus heteromorphus* are mentioned as a biostratigraphic criterion for the correlation of the Medokýš Mb. as well as isochronous units from Hungary (Kazár Member) with the Lower Karpatian (Vass, 1995; Horváth and Nagymarosi, 1979; Hámor, 1985). The FAD of *Sphenolithus heteromorphus* does not indicate the Karpatian age of the "*Rzehakia* (*Oncophora*) Beds", because 18.2 Ma is given for its FAD (Berggren et al., 1995). This age falls with in the middle part of the Ottnangian (range of Ottnangian 18.8-17.3 Ma, Rögl, 1998). The FAD of *Uvigerina graciliformis* was defined at the Ottnangian/Karpatian boundary (Cicha et al., 1983; Cicha et al., 1998) but the recent studies shift FAD of the small-sized *Uvigerina graciliformis* to the Upper Ottnangian (Cicha, pers. comm.; Salaj, 1997). Therefore, this biostratigraphic marker cannot solve the Upper Ottnangian vs. Karpatian age of the "*Rzehakia* (*Oncophora*) Beds". The isochroneity of the „*Rzehakia (Oncophora)* Beds" in the Central Paratethys can be interpreted on the basis of a climatostratigraphic event supposed for the sedimentation of the „Beds" . Cooling was suggested by Čtyroký (1987, 1991), a short humid episode by Krhovský et al. (1995). Planderová 1990 interpreted cooling for the Plachtince Mb. New palynological study from the South Slovak depressions (Doláková and Holcová, in prep.) indicated humid but warm climate. A climatic event can be also interpreted from the abundant occurrence of suspension-transported foraminifers. Storm waves are necessary for the widespread occurrence of tests transported this way. Such widespread occurrences of suspension-transported tests are unknow from other stratigraphical levels in the Central Paratethys. In agreement with the occurrences of suspension-transported tests, tempestites were described from the "*Rzehakia (Oncophora)* Beds" in the Nógrád Basin (Hámor, 1985; Vass and Beláček, 1998). Hummocky cross-stratification and laminae of shell detritus were observed also in the Upper Austrian Molasse. Tempestites were described also from other Upper Ottnangian Central Paratethys sediments: e.g., Řehánek and Salaj in Salaj (1997) described tempestites from the Upper Ottnangian of the Carpathian Foredeep. Based on the previous discussion, the Upper Ottnangian age is interpreted for the Medokýš Mb.

The discrepancy in the transgressive vs. regressive character of the "Beds" in the Central Paratethys may be caused by tectonic events at the Ottnangian/Karpatian boundary. This event is dated approximately to 17 - 18 Ma, when transpressional and/or transtensional regime was replaced by a tensional regime (Márton et al., 1995). The event induced paleogeographic changes, which are connected with the penetration of sea in to the South Slovak depressions and therefore caused the transgressive character of the Medokýš Mb. Shallow-water and euryhaline foraminiferal assemblages and many reworked species of calcareous nannoplankton indicate the low-stand character of this cycle of the 4st order. It may be correlated with global sea-level fall between global sea-level cycles TB 2.1 and TB 2.2. (Haq, 1991).

The "*Rzehakia (Oncophora)* Beds"-cycle can be correlated with the "*Ammonia*-Beds" described from the northern part of the Vienna Basin (Dobrá Voda Depression; Kováč et al., 1991) and the northern part of the Danube Basin (Bánovce Depression; Brestenská, 1977). These strata overlie the low-oxic and, in the upper part, hyposaline Eggenburgian-Ottnangian sediments, and also have a transgressive character. This may indicate re-opening of sea-ways between the South Slovak depressions and the Bánovce Depression, as confirmed finds of endemic foraminifer *Monspeliensina* in both basins.

Similarly to the older Ottnangian ingression, two marine sea-ways connecting the Nógrad/Novohrad basin with other central Paratethys basins are interpreted for the "*Oncophora* Beds" time interval:

(i) "old" way connecting the Alpine Foredeep and Central Paratethys. This way was euryhaline in the "*Rzehakia (Oncophora)* Beds" time interval and did not bring biostratigraphically new elements to the Upper Austrian Molasse. It is supposed that this is how euryhaline genus *Monspeliensina* penetrated from the Upper Austrian Molasse to the Nógrád Basin.

(ii) "new" way through the "Trans-Tethyan Trench Corridor", which enabled the penetration of biostratigraphically new elements such as *Uvigerina graciliformis* and *Sphenolithus heteromorphus* from the Mediterranean. This way was opened during the younger marine ingressions. This marine basin is interpreted as a source area of suspension-transported lower neritic to upper bathyal foraminifers.

Diversified and abundant foraminiferal assemblages in the "*Rzehakia (Oncophora)* Beds" from the South Slovak Basin may confirm the hypothesis that the South Slovak depressions was located at the "crossing" of these two ways.

Interpretation of the Medokýš Mb. as a diachronous facies representing marginal parts of the basin, which can be correlated with the whole Modrý Kameň Fm., appeared in Vass et al. (1979). A detailed study of foraminiferal assemblages from this marginal facies (e.g., VVL-6 borehole) showed that they can be distinguished from the foraminifers from the Medokýš Mb.: they contain more diversified foraminiferal assemblages, which are relatively small-sized but not size-sorted, and represent marginal facies of the Sečianky Mb.

Krtíš Mb. was defined, between the Sečianky Mb. and Medokýš Mb. This member is represented by littoral sandstones (Vass et al., 1992) and contains practically no foraminifers and calcareous nannoplankton with the exception of very rare assemblages of cibicidoids, which may be reworked. The Member was paleoecologically interpreted from the rare assemblages of Molusca.

(3) Karpatian sea-level cycle represented by deposition of Sečianky Mb.

Sečianky Mb. represents sediments with rich diversified marine microfauna, which can be used for detailed analysis.

Foraminiferal assemblages are typical indigenous assemblages without size-sorting and breaking of tests. In the South Slovak depressions, indigenous foraminiferal assemblages dominate. Reworked tests appear rarely in the lowemost part of sections. Suspension-transported tests were found in boreholes from marginal parts of the basin. In the central part of the basin (LKŠ-1 borehole), foraminiferal assemblages are diversified, lower neritic to bathyal (a list of species was published by Zlinská and Šutovská, 1990). Sedimentation started with a thin horizon with hyposaline assemblages (small-sized ammonias dominated). This horizon is overlain by normal marine sedimentation. The assemblages indicate good aeration in the basal horizon. Then euryoxibiont taxa (bolivinas, uvigerinas, globocassidulinas) dominated in assemblages at different depth zones of the basin (type (2) of distribution of euryoxibiont assemblages from the previous chapter). Paleodepths changed from the lower neritic to bathyal. Bathyal assemblages described in the LKŠ-1 borehole (Zlinská and Šutovská, 1990) represent the deepest assemblages in the whole history of the South Slovak depressions. Cibicidoids (mainly *Cibicidoides pseudoungerianus*) dominate in assemblages from the marginal part of the basin (GK-4, MV-14, VVL-6). *Ammonia parkinsonia* significantly prevails in nearshore assemblages (M-111 borehole) comprising 50-100 % of the assemblages.

A detailed quantitative analysis of foraminiferal assemblages enabled to distinguish 3 cycles (Holcová, 1999). The upper part of the 3rd cycle is missing. As cyclical changes of quantitative characteristics are well correlated with changes in paleodepth, cycles are very probably caused by sea-level changes of the 4th order. From other Paratethys regions, three cycles of sea-level oscillation were distinguished in the northern part of the Danube Basin (Holcová, 1999). Data for the interpretation of cyclical changes in the Karpatian sediments were published by Hámor (1985) from the time-equivalent of Sečianky Mb. named "Garáb schlier" and Brzobohatý (1993) from the Carpathian Foredeep in Moravia. In both areas, three cycles of sea-level changes were distinguished, which is in agreement with the observations described in the South Slovak depressions.

Foraminiferal tests are not influenced by diagenetic changes. Therefore, isotope analyses of tests cane be done (Šutovská and Kantor, 1991). Changes in oxygen isotope composition may be caused by temperature fluctuations as well as salinity fluctuations. The more probable interpretation for an abrupt change in oxygen isotope composition is the fluctuation in salinity and input of open-marine water to the Central Paratethys basins well correlable with horizons between cycles of sea-level changes of the 4th order. The gradual, moderate changes of oxygen isotope composition may be correlated with changes in paleotemperature: a moderate rise in temperature can be interpreted for the lower part of the Sečianky Mb., moderate cooling for its upper part. This is in agreement with the palynological study of Planderová (e.g. Planderová and Konzalová, 1989). Paleoproductivity can be evaluated on the basis of changes in carbon isotope composition. The good correlation between the abundances of calcareous nannoplankton and planktonic foraminifers and changes in carbon isotope compositions allow to interpret low productictivity in the lower part of the profile and a higher productivity in the upper part.

Calcareous nannoplankton assemblages are dominated by *Coccolithus pelagicus*. *Helicosphaera ampliaperta* and *Sphenolithus heteromorphus* occur among biostratigraphically significant species. Reworked species (mainly Oligocene and Cretaceous, rarely Eocene) occur in the lower part of the member and around boundaries between cycles of sea-level changes of the 4th order. Abundances of diatoms can be well correlated with the amounts of volcanic material.

Paleogeographical changes described from the Central Paratethys between the sedimentation of the "*Rzehakia (Oncophora)* Beds" and the Karpatian Schlier (Rögl 1998) were not recorded in the detailed morphology of the Nógrád Basin. The deepest parts of basin are situated at the SE margin of the area of Karpatian sediments (Fig. 7) similarly to the upper part of the Eggenburgian and Ottnangian and this paleogeography reflects existence of structure of the Dačov Lom graben (Vass et al., 1979) to the Karpatian.. Eastern marginal part of the basin was transected by the Dobroda Fault also similarly to the Ottnangian basin. Karpatian marine flooding was more extensive than the Ottnangian ones, reaching farther west. Re-opening of communication paths between the South Slovak depressions and the Bánovce depression during the uppermost Ottnangian can be interpreted from the statistical analysis of foraminiferal assemblages (Šutovská et al., 1993). Penetration of new fauna was not observed. All biostratigraphically new species appear below the Ottnangian/Karpatian boundary in the Plachtince and Medokýš Mbs., which is caused by opening of the "Trans-Tethyan trench corridor". Differences in species composition between the Sečianky and Medokýš Mbs. are defined by differences in paleoecological conditions.

The Sečianky Mb. represents transgressive and highstand parts the cycle of sea-level changes, which can be correlated with global sea-level cycle TB 2.2. The upper part of the cycle (probably with *Globigerinoides bisphericus)* was eroded as confirmed by the study of smectite from the underlying Plachtince Mb. (Vass and Šucha 1994). This study shows that the original thickness of the Modrý Kameň Fm. (Upper Ottnangian, Karpatian) was 1000 m, as opposed to the present-day maximum thickness of about 400 m.

The Lower Badenian basin

4. 2. 9. Time interval between FAD of *Praeorbulina* and FAD of *Orbulina* (lower part of Early Badenian)

In the South Slovak depressions, only one specimen of *Praeorbulina* was recorded. Therefore, interpretation of this time interval in the South Slovak depressions is not fully reliable. This specimens were recorded in the strata described as the Medokýš Mb. from the surroundings of Ľuboriečka (Holcová et al., 1996). These strata contain suspension-transported foraminifers generally identical with the assemblages from the Medokýš Mb. The occurrence of *Praeorbulina* indicates redeposition of these tests into younger sediments correlated with the lowermost Badenian. A detailed statistical analysis showed that reworking of tests changed species composition of the assemblages, and the reworked assemblages are not fully identical with the assemblages from the Sečianky Mb. (Holcová and Maslowská, 1999). Character of microfauna showed that paleoenvironment was not suitable for appaerence of full marine fauna and therefore praeorbulinas are rare.

The character of sediments with *Praeorbulina* from the South Slovak depressions is comparable with that of sediments described by Cicha (1995) from the Alpine-Carpathian Foredeep. Cicha (1995) described lowstand sediments from the Karpatian - Badenian boundary with rare *Praeorbulina* overlain by transgressive sediments with *Orbulina*. The lowstand character of sediments with *Praeorbulina* in the South Slovak depressions is confirmed by predominance of reworked species. On the second hand, the sediments are in transgressive position: they overlie Ottnangian sediments and seem to represent basal transgressive sediments of the Badenian transgression. Hiatus is interpreted between them and the members with marine fauna from the Vinica Fm. (missing of interval with coexistence of *Orbulina* and *Praeorbulina*). The sediments with *Praeorbulina* may represent a whole cycle of sea-level changes of the 4th order with low amplitude corresponding to global sea-level fall between the TB 2.2. and TB 2.3. cycles.

These sediments may be correlated with the Príbelce Mb. which does not contain stratigraphically significant species. The Príbelce Member was sedimentologically described by Vass (1977). Reworked Oligocene and Miocene poorly preserved nannoliths prevailed in this member (Zlinská and Šutovská, 1991). Correlation with transitional Karpatian/Badenian sediments described by Kantorová (1965) from GK-4 borehole and Kučerová (1980) from BE-2 borehole is still questionable. Their stratigraphical interpretations lack biostratigraphic evidence.

Paleogeographical interpretation for this time interval is impossible because only fragmentary data exist about this interval.

4. 2. 9. Time interval between FAD of *Orbulina* and emergence of the area (upper part of Early Badenian)

Interval with co-existence of *Praeorbulina* and *Orbulina* described in most Central Paratethys basins was not recorded in the South Slovak depressions. Therefore, the Early Badenian transgression, significant for the whole Central Paratethys (Rögl, 1998) is younger in the South Slovak depressions is later than in other Central Paratethys basins. It may be caused by the uplift of area which is reflected in extensive erosion of the Karpatian sediment.

The FAD of *Orbulina* is correlated with the penetration of new diversified and abundant foraminiferal assemblages to the South Slovak depressions. Assemblages are well preserved and well size-sorted, indigenous. Lower neritic assemblages are composed of diversiefied benthonic foraminifers and abundant large planktonic foraminifers with *Orbulina*. The upper neritic assemblages contain mainly epiphytic species (*Rosalina, Asterigerinata, Lobatula*). *Amphistegina* appers in these assemblages. All assemblages indicate good aeration of the whole basin. Calcareous nannoplankton assemblages are diversified and abundant, with commonly occurring *Helicosphaera kamptneri*. Cretaceous, Eocene and Oligocene redepositions are rare.

Morphology of the marine basin was significantly influenced by volcanic activity. The depocentre of the basin was shifted from the area of the Strháre-Trenč Graben to the western part of the basin when the basin continued to the Danube Basin. Gradual eastward shallowing of the basin can be interpreted. Direction of marine transgression was different than in the Karpatian: transgression came from the Danube Basin. Communication with the Bánovce Basin was closed.

The Badenian transgression is correlated with cycle TB 2.3. of global sea-level changes (Vass, 1995; Rögl, 1998; Kováč et al., in print). The base of the cycle in the South Slovak depressions is younger than other Central Paratethys basins, which may be caused by uplift of area in the upper part of Karpatian.

Conclusion

(1) The following new methods were used for a detailed reconstruction of Oligocene and Miocene marine basins preserved in the area of present-day South Slovak depressions,:

(i) biostratigraphic correlation based on the LADs and FADs of biostratigraphically significant planktonic foraminiferal and calcareous nannoplankton species;

(ii) taphonomical analysis of foraminiferal assemblages;

(iii) analysis of abundance of reworked species (foraminifers, calcareous nannoplankton);

(iv) multivariate statistics;

(v) paleoecological synthesis as an indicator of tectonic activity.

(2) Among 14 LADs and FADs significant for the studied time interval, eight were chosen for the definition of nine time intervals. Based on foraminiferal and calcareous nannoplankton assemblages, these intervals were characterized paleoecologically and paleogeographically (Fig. 9).

(3) New biostratigraphic division permitted to define changes in basin geometry between the Buda Basin, Fiľakovo/Pétervásara Basin and Novohrad/Nógrád Basin as continuous, relatively long-lasting processes. The existence of short-lived Fiľakovo/Pétervásara Basin can be correlated with a tectonic event dated to 19-20 Ma.

(4) Shift of depocentres, generally from the east to the west (in present-day coordinates) was observed in the interval from the Kiscellian to the Early Badenian.

(5) Existence of the following tectonic lines can be demonstrated on the basis of detailed paleoecological study:

(i) Plešivec-Rapovce Fault in the Kiscellian and Egerian;

(ii) Dobroda Fault in the Ottnangian and Karpatian.

Fiľakovo Fault may have played some role in the Eggenburgian.

From the Eggenburgian to the Karpatian, location of depocentres reflected influence of structure of the Dačov Lom graben on paleogeography.

(6) Study of reworked species, abundance of foraminifers and paleodepth changes were used for a detailed analysis of sea-level cycles in monotonous sediments.

(7) Local sea-level changes can be well correlated with global changes in the Kiscellian and Karpatian. They may indicate periods of low tectonic activity. Limited correlations can be done for the Eggenburgian, upper part of the Ottnangian and for the Early Badenian. Short-time tectonic events can be expected during this time interval. Correlation with global sea-level changes is questionable during the Egerian. This period can be characterized by significant tectonic activity.

(8) Communication with East Slovakia, Bánovce Depression and Várpalota area can be confirmed by the following micropaleontological data:

(i) occurrence of the deepest foraminiferal assemblages in the NE margin of the South Slovak depressions during the upper part of the Egerian (communication with the Flysh Basin in the East Slovakia);

(ii) isolated occurrences of Eggenburgian foraminiferal assemblages in sediments underlie the volcanics of the Krupina Plateau (communication with the Bánovce Depression);

(iii) penetration of foraminiferal genus *Monspeliensina* to the South Slovak depressions in the uppermost Ottnangian (communication with the Bánovce Depression);

(iv) penetration of small-sized *Uvigerina graciliformis* to the South Slovak depressions in the uppermost Ottnangian (communication with Várpalota area);

(v) similarity of benthonic foraminiferal assemblages revealed by multivariate statistical methods in the Karpatian (communication with the Bánovce Depression).

(9) Distribution of low-oxic foraminiferal assemblages can be used as an indicator of the development of marine basins: Kiscellian is characterized by widespread occurrence of low-oxic assemblages, which indicates a period of long-lasting unchanged environment, tectonically inactive with low circulation of bottom waters.

The Egerian, upper part of the Eggenburgian and partly Karpatian are characterized by episodical and local occurrence of low-oxic assemblages, which can be interpreted as periods with depth-diversified bottom, tectonically active when low-oxic environment persisted only for short time in partly isolated small parts of the basin. Other time intervals (lower part of the Eggenburgian, Ottnan-

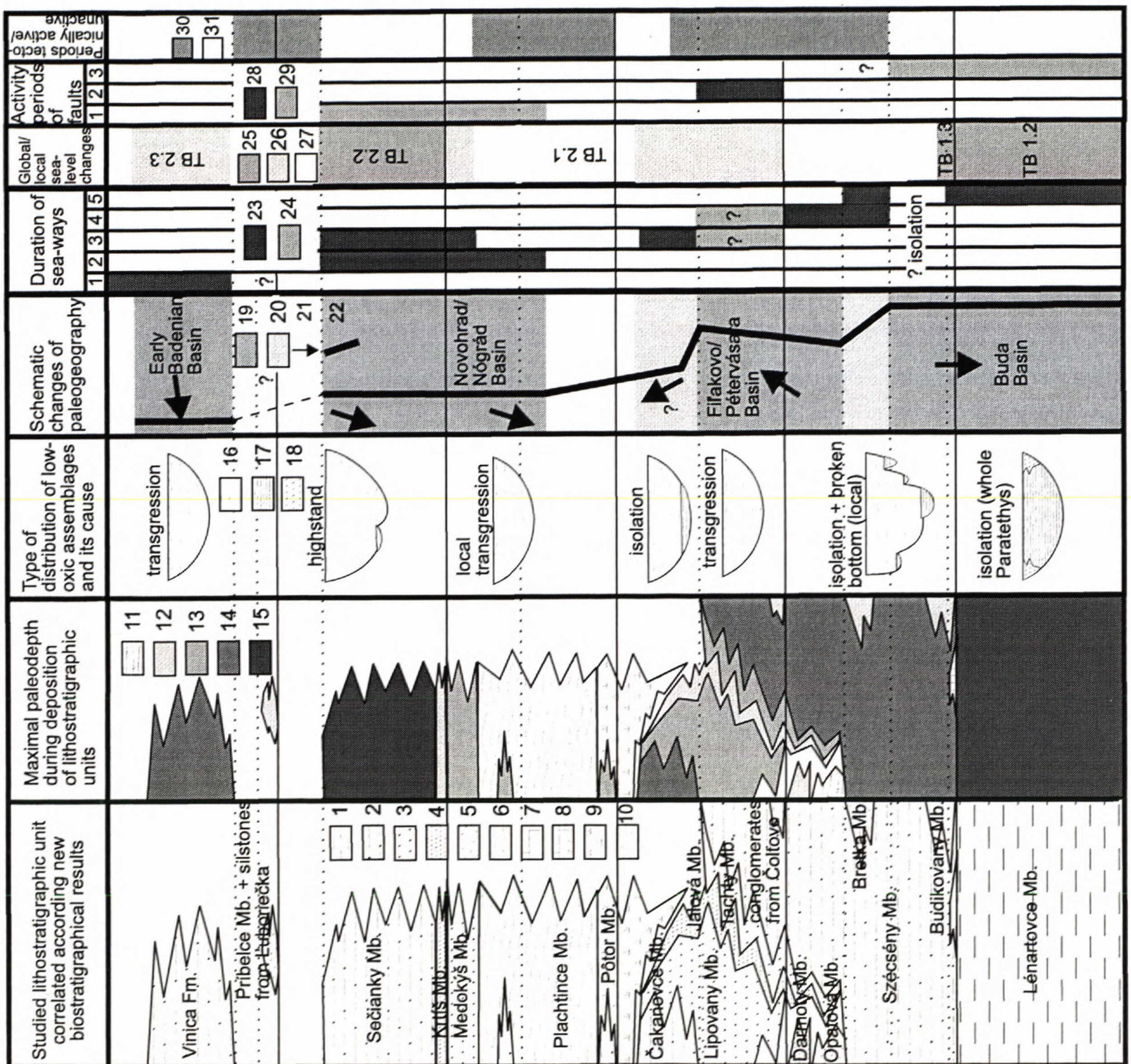

Fig. 9. Synthesis of new data related to the Oligocene and Miocene marine evolution of the South Slovak depressions. 1 – claystones, 2 – silstones, 3 – sandstones, 4 – coarse-grained sandstones, 5 – fine-grained sandstones with beds of coarse-grained sandstones and conglomerates, 6 – conglomerates, 7 – limestones, 8 – limestones and conglomerates, 9 – terrestrial deposits, 10 – fluviolacustrine deposits; 11 – deltaic deposits, 12 – shallow-water, +/- hyposaline environment, 13 – upper neritic, 14 – lower neritic, 15 – bathyal; 16 – normal marine, well-aerated environment, 17 – low-oxic, 18 – hyposaline; 19 – period with typical paleogeography of the basin, 20 – transitional period, 21 – general direction of deepening of basin; 22 – changes in locations of depocentres approximately from E to W, 23 – period with the existence of a sea-way, 24 – period with a questionable existence of a sea-way (1 – communication with

gian, Early Badenian) are characterized by good aeration of the whole basin indicating a good communication of the South Slovak depressions with the surrounding basins.

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the Danube Basin, 2 – communication with Várpalota area, 3 – communication with the Bánovce Depression, 4 – communication with the East Slovakia, 5 – communication with the Buda Basin in Hungary); 25 – period of good correlation between local and global sea-level changes, 26– period with limited correlation between global and local sea-level changes, 27 – period with no correlation between local and global sea-level changes; 28 – deposits deformed by faulting, 29 – proposed synsedimentary activity of faults (1 – Dobroda Fault, 2 – Fiľakovo Fault, 3 – Plešivec–Rapovce Fault); 30 – tectonically active periods, 31 – tectonically inactive periods.

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Analysis of small foraminifera assemblages and clay minerals from bentonite-like layers within Czerwin beds (Subsilesian Unit, Polish Flysch Carpathians) – preliminary results

[1]DOROTA SALATA, [2]ANNA WASKOWSKA-OLIWA and [3]MAREK CIESZKOWSKI

[1,2,3]Institute of Geological Sciences, the Jagiellonian University, Oleandry st. 2a, 30-063 Kraków.
agat@ing.uj.edu.pl, oliwa@ing.uj.edu.pl, mark@ing.uj.edu.pl

Abstract: Two bentonite-like layers were found in the Czerwin beds (Wisniowa tectonic window). Their Early Eocene age was established on the basis of the presence of *Saccamminoides carpathicus* Geroch and the numerous occurrence of *Glomospira* div. sp. In terms of micropaleontological and mineralogical features the deposits stand out between neighbouring layers. Foraminifera tests from the bentonite are small, white and the number of them changes. Clay minerals are represented essentially by a smectite. Taking into consideration all features of bentonites their volcanic origin is possible.

Key words: Subsilesian Unit; Early Eocene; bentonites; clay minerals; smectites; small foraminifera

The area of investigations

The studied formations are situated in Paleogene sediments of Czerwin beds (the Subsilesian Unit in the Wisniowa tectonic window) (fig.1). The Czerwin beds are represented by grey shales with intercalations of thin-bedded fine-grained glauconitic sandstones.

The denomination „bentonite horizons" is used to denote claystone layers of 17 (No. of samples: 15, 16, 17, 18) and 0,5 (No. 9) (fig. 2) centimetres of thickness which stand out between others. The layers are almost white colour. They have sharp bottom and top boundaries and they swell in water.

Micropaleontological analyses

For microfaunal analyses, 22 100-gram samples were collected from soft shales (fig. 2). The material was subjected to maceration process in the solution of Glauber's salt. Then, samples were washed over a 63 μm screen and dried. All tests were then picked from the dry residue, counted and identified.

The assemblage of foraminifera from the bentonite horizon consists essentially of well preserved agglutinated species (98.25 % – 100 %). Planctonic and benthic calcareous foraminifera are sparse (2 % – 0 %) and are badly preserved. Tests of about 90 % of the foraminifera are white, smooth on the surface and built up of finer material then typical grey tests.

The age of the analysed material was established on the basis of the agglutinated foraminifera assemblages which point to Early Eocene zones: Glomospira div. sp. and Saccamminoides carpathicus (zones after Olszewska, 1997).

The predominant genus is *Glomospira* with *Glomospira charoides* (JONES et PARKER) and *Glomospira gordialis* (JONES et PARKER) being the most numerous species. In bentonites, the genus comprises 70 % of all foraminifera while in adhering layers its number decreases to 35 %. The other species of *Glomospira* are single. In the sediment the following benthonic foraminifera are also present: *Abysammina poagi* SCHINTKER et TJALSMA, *Ammosphaeroidina pseudopauciloculata* (MJATLIUK), *Ammodiscus* div. sp., *Arenobulimina dorbigny* (Reuss), *Gerochammina conversa* (GRZYBOWSKI), *Glomospirella grzybowskii* (JURKIEWICZ), *Haplophragmoides* div. sp., *Hormosina* div. sp., *Hyperammina* sp., *Karrerulina coniformis* (GRZYBOWSKI), *Nuttallides trüempy* (NUTTALL), *Paratrochamminoides* div. sp., *Precystammina* sp., *Recurvoides* div. sp., *Rhabdammina cylindrica* GLEASSNER, *Trochammina* div. sp., *Saccammina placenta* (GRZYBOWSKI). Planctonic foraminifera are represented by *Acarinina soldadensis* (BOLI) and *Subbotina velascoensis* (CUSHMAN).

The number of foraminifera within bentonite decreases from the bottom towards the top and changes as follows: 621 f/100 (No. of foraminifera/100 grams of sediment), 259 f/100, 102 f/100 and 20 f/100. Simultaneously the general amount of microfauna of upper and lower deposits averages 210 f/100.

Comparison of test's size has revealed that foraminifera deriving from bentonite are smaller then average and the end parts of their tests are anomalously coiled. The range of their diameter varies between 0.3 and 1.5 mm, but over 50 % of them belong to a very narrow range of size 0.4–0.7 mm. In the neighbouring layers the size of *Glomospira* varies in size from 0.5 to 2.5 mm though the biggest percent of them comprises in the range of 0.7–1.0 mm. Besides their tests are typically coiled. For measurement *Glomospira charoides* (JONES et PARKER) and *Glomospira gordialis* (JONES et PARKER) were chosen as they are present in every sample.

The EDS analyses of the chemical composition of tests of the same species of agglutinated forms from the bentonite and typical foraminifera have not revealed differences in their mineralogical composition.

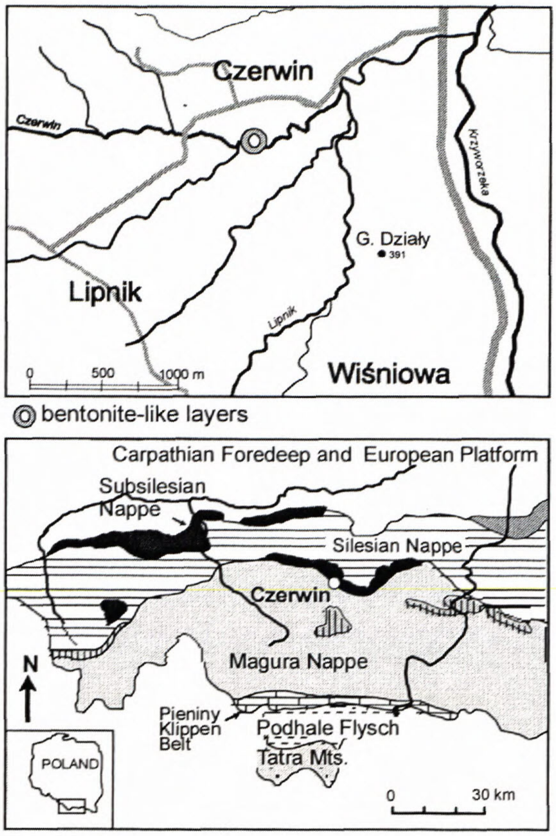

Fig.1. Location of bentonite-like layers.

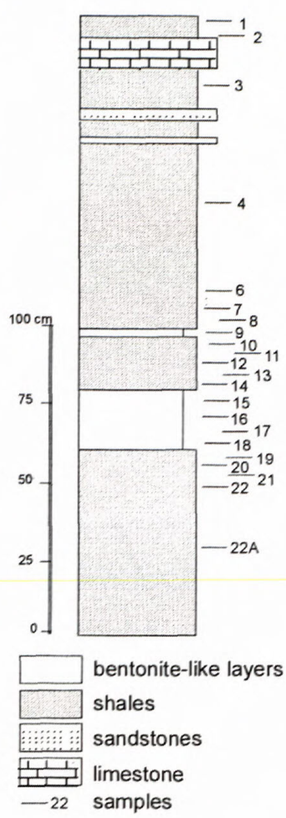

Fig.2. Litological log.

The XRD patterns show that, in contrast to under- and overlying sediments, the clay material of bentonites consists essentially of montmorillonite. Besides the <0,2 μm fraction of samples, 15 and 17 is represented by pure smectite (fig. 3).

Minerals accompanying smectites in fractions <2–0,2 μm and <2–63 μm are: kaolinite, chlorite, mica and quartz. Between top and bottom of the lower layer of bentonites (fig. 1) there is noticeable difference in the amount of kaolinite and quartz. Towards the top of the layer the amount of kaolinite decreases while the amount of quartz increases. The upper layer of bentonites has high and equal proportions of kaolinite and quartz.

Discussion

The numerous occurrence of foraminifera of *Glomospira* genus in the Early Eocene has biostratigraphical value (sc. *Glomospira* Event) (KAMINSKI et al., 1996). The foraminifera of the *Glomospira* genus are detritus feeding organisms living on the surface of the sediment (mobile epifauna). The genus is well adapted to environments of high productivity and low oxygenation and it settles niches that undergone rapid change (Kaminski et al., 1996).

There could had been two reasons for such a plentiful occurrence of *Glomospira*: 1) global: acme zone of forms of the genus, 2) local: change of palaeoecological conditions (change of type of sediment). Anomalies connected with size, test's shape and composition of foraminifera assemblages could be the result of adaptation to adverse living conditions.

Taking into consideration the clay composition (montmorillonite, lack of detritic material) of bentonite layers their volcanic origin (alteration of volcanic ashes in the sedimentation basin of the investigated area) is not out of question and further study leading to explanation of the problem is being made.

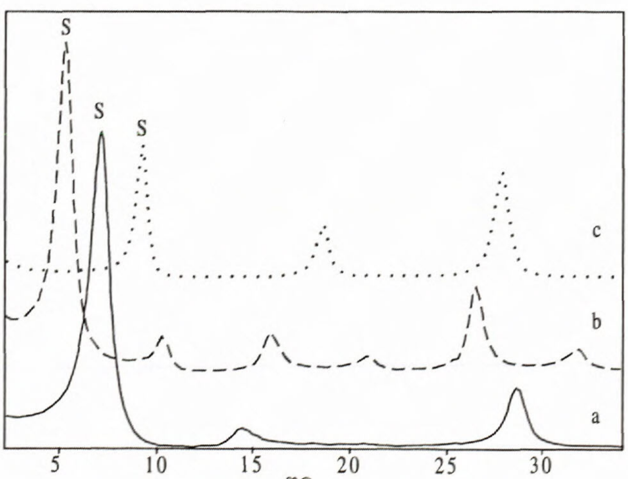

Fig. 3 XRD patterns of smectite (S) from the bentonite (cz. 17, fig. 2) of oriented preparations of < 0.2 m fraction: a – air dried, b – glycolated, c – heated in the temperature of 550 °C.

Analyse of clay minerals

Analyses were carried out on samples derived from two bentonite-type layers from Czerwin as well as those occurring below and under the bentonite in the cross-section of the Czerwin area.

Clay minerals were investigated in air-dried, glycolated and heated in the temperature of 550 °C oriented preparations from fractions: 63–2 μm, 2–0.2 μm and <0,2 μm. Diffraction patterns of samples were recorded in the range 2-65° of the 2Θ angle.

Acknowledgement

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Borové Formation of Middle Eocene age east of the Tatra Mts.

STANISLAV BUČEK

Geological Survey of Slovak Republic, Mlynská dolina 1, 817 04 Bratislava, Slovak Republic

Abstract. Recently in stratigraphic literature the opinion has become common that in the Paleogene of the Subtatric Group the Borové Formation becomes younger from west to east and/or from NW to SE as a consequence of gradual transgression in this direction. The study of literature and examination of samples from Kamenica and borehole Lipany-6 show that the Middle Eocene basal formation was also deposited east of the Tatra Mts. as far as the area of Sabinov. Associations of Middle Eocene larger foraminifers (characterized by the species *Nummulites puschi* D'ARCHIAC, *N. perforatus* (MONTFORT), *Assilina schwageri* (SILVESTRI)) belonging to the SBZ Zone 17 (38-41 m.y.) were found in situ, in blocks in the Pucov Member, in pebbles of the Šambron Member and as isolated tests redeposited into the Šambron Member. The composition of the associations of larger foraminifers testifies to the fact that there is continuation of the Borové Formation which was deposited at the northern slopes of the Tatry Mts. Different ages of the transgressive consequence of the transgression of the Eocene sea into an environment highly dissected morphologically which formed barriers to the advancing sea. Frequent redeposition of larger foraminifers tests from the Borové Formation into the Šambron Member testifies to considerable tectonic unrest in the time of sedimentation of the Šambron Member and intense disintegration of the Borové Formation in that time (due to sinking sea level it could have been partly uncovered and eroded).

Key words: Subtatric Group, Borové Formation, Šambron Member, larger foraminifers, Middle Eocene, SBZ 17, area east of the Tatra Mts.

Introduction

In the year 1963 Andrusov & Köhler called attention to the fact that with extensive transgression in the second half of the Eocene the sea did not cover the territory of the Western Carpathians at once, but gradually, some areas were not flooded at all (e. g. the Spišsko-gemerské rudohorie Mts. or Nízke Tatry Mts. (Kráľ 1977)). The tendency of gradual rejuvenation of the transgressive formation (Borové Formation in the sense of Gross et al. 1984) from NW to SE in the Liptovská kotlina depression was recorded by Gross & Köhler et al. (1980) and for the Paleogene of the Subtatric Group of the Western Carpathians generalised by Köhler & Salaj (1997) and Buček et al. (1998). Detailed examination of the data from literature as well as investigations in the last time have shown that the Middle Eocene transgression reached the area far to the east from the Tatra Mts.

Latest knowledge on the geological structure and lithostratigraphy of the Subtatric Group to the east of the Tatra Mts. are summarized in the work by Gross et al. (1999a, b) and Janočko et al. (2000a, b) and it is not necessary to repeat it here.

Data in literature

At the eastern margin of the Tatra Mts. basal Paleogene sediments of Middle Eocene age (= Bartonian according to present-day terminology, compare Serra-Kiel et al. 1998) are already not found in situ nowadays and according to Bieda (1963) and Köhler (in Janočko et al. 1999, 2000b) the basal formation between Tatranská Kotlina and Ždiar (Spišská Magura Mts.) is of Upper Eocene (Priabonian) age. However, in the conglomerate body overlying the basal beds (in the Pucov Member in the sense of Gross et al. 1982, 1984) near Ždiar Vaňová (1962), Marschalko & Radomski (1970) and Köhler (in Janočko et al., l.c.) found pebbles to blocks of dark-grey sandy limestones with tests of *Nummulites puschi* D'ARCHIAC, *N. brongniarti* D'ARCHIAC et HAIME and *N. perforatus* (MONTF.) which are indubitably of Middle Eocene age. With regard to the size of blocks transportation at a greater distance is excluded and it rather should be supposed that the basal Paleogene Formation covered a larger part of the Tatra Mts. than at present. Already in the Upper Eocene erosion and displacement of sediment in form of blocks into the Pucov Member could have taken place in the area of the present-day Tatra Mts.

The occurrence of the Borové Formation at Veľká Kýčera (elevation point 966) west of Vyšné Ružbachy (Spišská Magura Mts.) is also known. According to Vaňová (in Nemčok & Vaňová 1977) dark compact limestones in mass amount contain the species *Nummulites perforatus* (MONTFORT) and discocylines. The mentioned authors also quote Bieda (1963) who from limestones covering the Ružbachy Mesozoic mentions the species *Nummulites rotularius* DESHAYES, *N. perforatus* (MONTF.) and *N. puschi* D'ARCHIAC, thus an association, which is often found at the northern slopes of the Tatra Mts. (compare Bieda 1963, Kulka 1984). The quotation is erroneous, because in the monograph from the year 1963 Bieda does not mention Paleogene sediments near Vyšné Ružbachy, probably an unpublished datum of this author is concerned.

Further data were provided by borehole PU-1 near Šambron in the Spišsko-Šarišské medzihorie Intermountains (Nemčok et al. 1977), which penetrated the lower part of the Šambron Member (cf. Samuel in Andrusov & Samuel et al. 1985, p. 252-253) with layers of conglomerates and sandstones, neither reached the basal beds, nor the substratum (terminal depth 2004 m). Larger foraminifers from the interval 29.1 to 1997 m were evaluated by Vaňová (in Nemčok et al., l.c.). She found tests in compact coarse grained sandstones and conglomerates and considered them as redeposited.

In the associations from the individual depth intervals are found the species *Nummulites variolarius* (LAMARCK), *N. gallensis* (HEIM), *N.* cf. *millecaput* BOUBÉE, *N. perforatus perforatus* (MONTFORT), *N. anomalus anomalus* HARPE, *N. puschi* D'ARCHIAC, *N. discorbinus* (SCHLOTHEIM), *N.* cf. *striatus striatus* (BRUGUIÉRE), *N. striatus pannonicus* (ROZLOZSNIK), *N. striatus minor* D'ARCHIAC, *N. incrassatus incrassatus* DE LA HARPE, *N.* cf. *chavannesi* DE LA HARPE, *N.*ex gr. *fabianii* (PREVER), *Operculinoides vaughani* COLE, *O. nassauensis* COLE (both these species are re-assigned to *Assilina gomezi* (COLOM et BAUZÁ)), *Discocyclina roberti llarenai* RUIZ DE GAONA and *Discocyclina fortisi* (D'ARCHIAC). Most frequent species *Nummulites puschi* D'ARCHIAC and *N. perforatus* (MONTFORT). The associations are mixed, composed of typically Middle Eocene and Upper Eocene forms. Their displacement took place in the Upper Eocene or later and on the basis of larger foraminifers the interval with the latter in borehole PU-1 Šambron is considered as Upper Eocene or even younger. Allochtonous are also associations of smaller foraminifers, pollen and spores.

The frequent presence of the species *Nummulites puschi* D'ARCHIAC and *N. perforatus* (MONTFORT) testifies to the fact that the original basal transgressive formation in the area of Šambron was Middle Eocene.

Nemčok & Vaňová (1977) also called attention to some slump bodies in sediments of the Subtatric Group east of the Tatra Mts. They mention the occurrence in Kamenica/Torysa r. (Spišsko-Šarišské medzihorie Intermts.) with species *Nummulites perforatus sismondai* D'ARCHIAC et HAIME in the Šambron Member. It is not clear why they consider this occurrence as Middle Eocene (Upper Lutetian- according to present-day terminology Bartonian) and do not take into account redeposition of larger foraminifers.

At the northern margin of the village Jakubovany (Spišsko-Šarišské medzihorie Intermts.) a slump body is found in the lower part of which Vaňová (in Nemčok & Vaňová 1977) identified the species *Nummulites variolarius* (LAMARCK), *N. perforatus perforatus* (MONTFORT), *N. anomalus anomalus* DE LA HARPE, *N. kovacsiensis* HANTKEN et MADARASZ, *Operculinoides* sp. and *Discocyclina* sp., in the slump body itself *N. perforatus perforatus* (MONTF.), *N. striatus minor* D'ARCHIAC et HAIME, *N. chavannesi* DE LA HARPE and *N. pulchellus* DE LA HARPE. Overlying the body the species *Nummulites variolarius* (LAMARCK), *N.* cf. *millecaput* BOUBÉE, *N. kovacsiensis* HANTKEN et MADARASZ, *Discocyclina roberti llarenai* RUIZ DE GAONA, *D. fortisi* (D'ARCHIAC) and *D. discus* (RÜTIMEYER). Slump body was ranged to the Lower Priabonian by Nemčok & Vaňová (l.c.). It again contains mixed Middle and Upper Eocene associations of larger foraminifers.

The quoted authors also mention further occurences of larger foraminifers in the Šambron Member. There are the localities Šarišské Dravce (*N. perforatus sismondai* D'ARCHIAC et HAIME and *N. incrassatus incrassatus* DE LA HARPE), Dlhý potok brook (*N. perforatus sismondai* D'ARCHIAC et HAIME, *N. perforatus perforatus* (MONTFORT), *N. anomalus anomalus* DE LA HARPE and *N.* cf. *striatus* (BRUGUIÉRE)). North of the village Jakubovany (form transitional from *Nummulites striatus minor* D'ARCHIAC et HAIME to *N. striatus pannonicus* (ROZLOZSNIK)) and south of the village Milpoš (sandstones with *Nummulites perforatus sismondai* D'ARCHIAC et HAIME, *N. perforatus perforatus* (MONTFORT), *N. incrassatus incrassatus* DE LA HARPE, *N. chavannesi* DE LA HARPE, *N.* cf. *budensis* HANTKEN and form transitional from *N. fabianii* (PREVER) to *N. fichteli fichteli* MICHELOTTI).

The presence of *Nummulites perforatus* (MONTFORT) in these associations indicates again that the original source of the material redeposited into Šambron Member were also rocks of transgressive lithofacies - the Borové Formation of Middle Eocene age.

In the year 1983 evaluation of borehole Lipany-1 was published (Leško et al. 1983). The borehole penetrated the Šambron Member (to depth of 2600 m), the basal Paleogene formation (2600 - 2747 m) and in the interval 2747 to 4000 m it drilled through Triassic rocks. Larger foraminifers from clasts and the groundmass were evaluated by Vaňová (in Leško et al., l.c.). In the Šambron Member (interval 660 to 2654 m) she found the species *Nummulites variolarius* (LAMARCK), *N. anomalus anomalus* DE LA HARPE, *N. perforatus perforatus* (MONTFORT), *N. perforatus sismondai* D'ARCHIAC et HAIME, *N. puschi* D'ARCHIAC, *N. striatus minor* D'ARCHIAC et HAIME and *Operculina parva* DOUVILLÉ. It is an association of Middle Eocene species. In the basal formation at depth of 2651 to 2653 m she found an Upper Eocene association consisting of *Nummulites chavannesi* DE LA HARPE, *N. pulchellus* DE LA HARPE, *N. bouillei* DE LA HARPE and *N. budensis* HANTKEN, but below depth of 2653 m only the Middle Eocene species *Nummulites perforatus perforatus* (MONTFORT), *N.* ex gr. *perforatus* (MONTFORT), *N. striatus minor* D'ARCHIAC et HAIME, *Operculina* sp. and *Discocyclina* sp. are found. The association testify to the fact that in borehole Lipany-1 the Borové Formation is Middle to Upper Eocene in age. The Šambron Member contains an association redeposited from the lower Middle Eocene part of the Borové Formation and their age was determined as Upper Eocene on the basis of pollen and spores (Snopková in Leško et al. 1983).

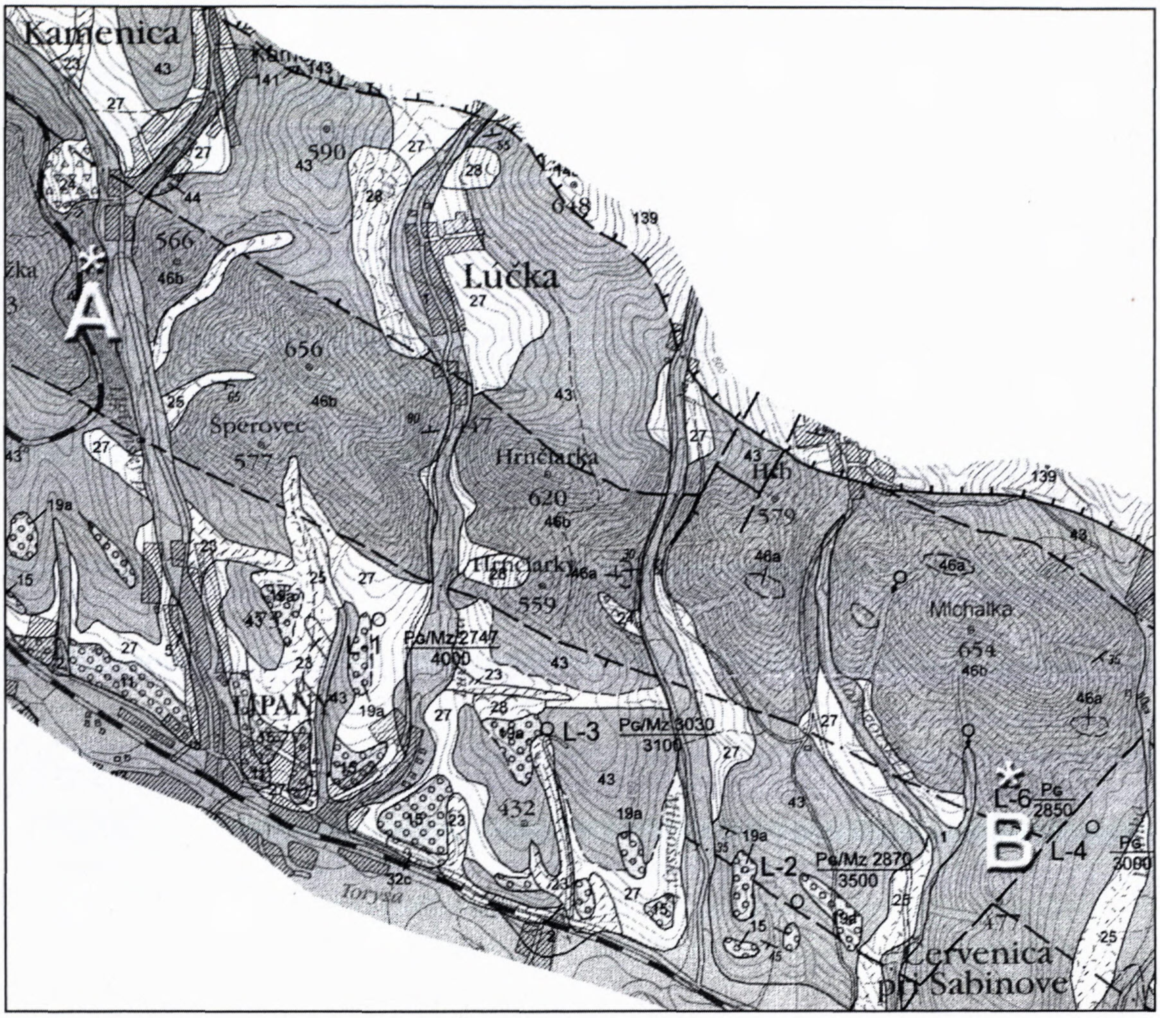

Fig. 1. Part of geological map 1: 50 000 (Gross et al. 1999) of the territory between the villages Kamenica and Červenica near Sabinov and localization of the localities: A - locality Kamenica, B - borehole Lipany-6.

Explanations: Quaternary (Holocene): 1 – fluvial sediments, 2 – proluvial flood plain loams; Quaternary (Pleistocene): 5 – fluvial sandy gravels, sandy gravels and loams of the bottom accumulation (Würm), 11 – fluvial sandy gravels and gravels (Younger Riss), 15 – fluvial sandy gravels and gravels (Older Riss), 19a – fluvial gravels and sandy gravels (Mindel); Quaternary undivided (Pleistocene/Holocene): 23 – deluvial-fluvial out-wash loams and sandy loams, 24 – loamy-stony, sandy, sandy-stony to stony screes, 25 – slope loams, 27 – deluviums, 28 – landslides; Tertiary (Neogene): 32c – conglomerates, sandstones (Lower Miocene); Subtatric Group, Huty Formation (Late Priabonian – Early Oligocene): 43 – claystones, clay-siltstones predominating over sandstones, 46a – Šambron Member, beds of polymict conglomerates, 46b – Šambron Member, fine-rhythmic flysch, or claystones; Klippen Belt: 139 – Proč-Jarmuta Formation, Carbonate flysch (Paleocene-Middle Eocene), 141 – red and grey-green sandy claystones (Paleocene–Middle Eocene), 143 – brick-red marlstones with sandy limestones intercalations (Cenomanian–Turonian).

New evaluations of larger foraminifers associations

The author had samples coming from the localities Kamenica (NW of the village Lipany) and from borehole Lipany-6 (NE of the village Červenica near Sabinov) available (see Fig. 1).

Kamenica

The Šambron Member in the railway cut near the railway station in Kamenica awakes deserved attention in the last time (Plašienka et al. 1998, Jacko 2000). During the excursion to this area the author with RNDr. P. Gross, CSc. obtained pebbles from a conglomerate layer in the Šambron Member at an abandoned quarry, which is situated about 250 m southeast of the railway station Kamenica (500 m W of el. p. 566). Six from the observed pebbles contain larger forams. Their evaluation is as follows:

Pebble 1 (Pl. I, Figs. 1-2): Extraclast-bioclastic, nummulitic sandy wackestone formed by fragments of quartz, carbonates and siltstones (average size 0.1 mm), scarce are glauconite grains (up to 0.3 mm). The cement is carbonate. The association of larger forams is formed by *Nummulites puschi* D'ARCHIAC, *N.* cf. *semicostatus* (KAUFMANN), *N. striatus minor* D'ARCHIAC et HAIME, *Assilina schwageri* (SILVESTRI), *Discocyclina sella* D'ARCHIAC and *Discocyclina* sp. Small fragments of coralline algae, cross sections of problematic alga *Pieninia oblonga* BORZA et MIŠÍK, fragments of cyclostomate

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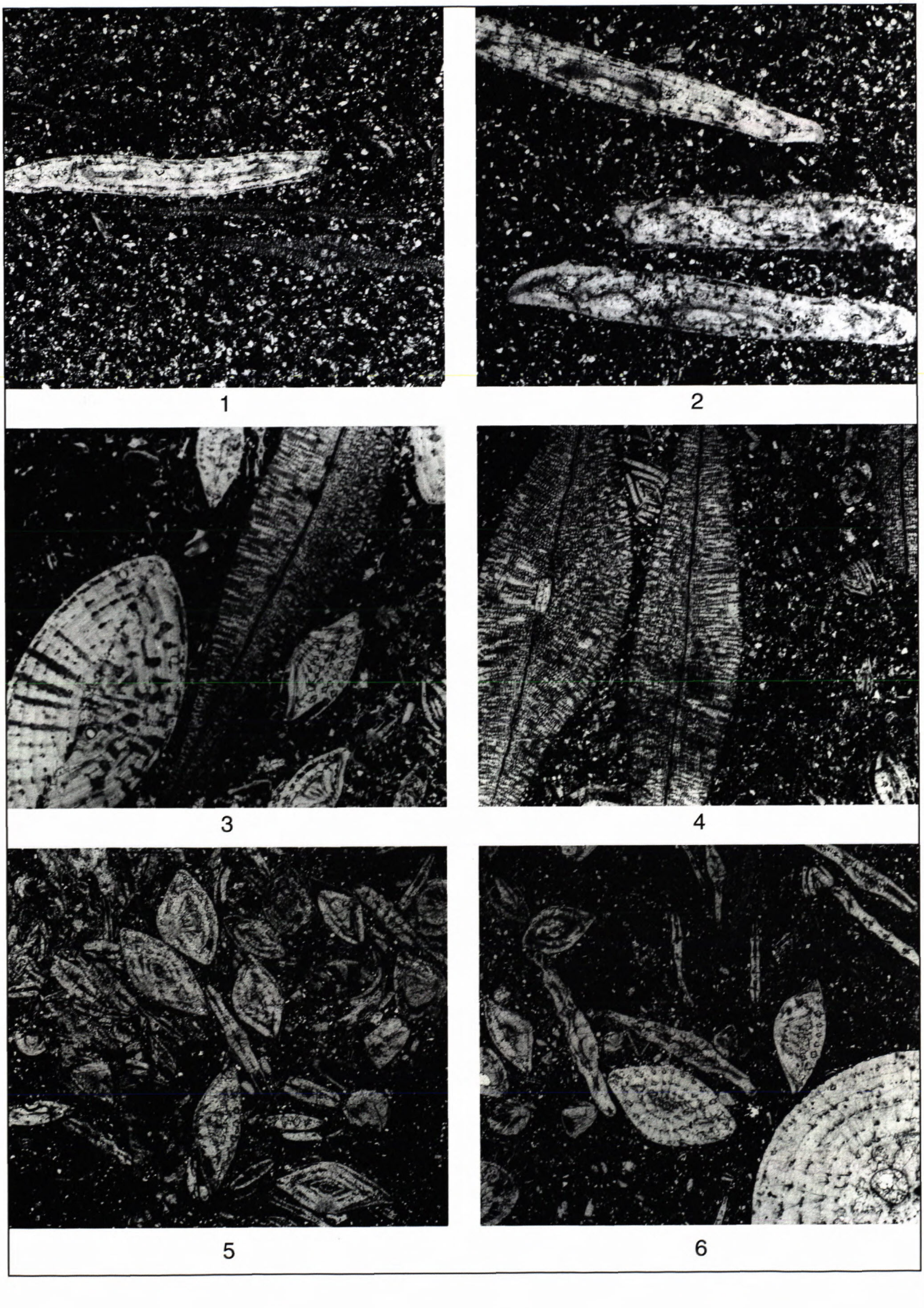

bryozoans, lamellibranchs, echinoid spines, worm tubes (*Ditrupa* sp.) are also not missing, from smaller forams rotalid, miliolid and agglutinate forms (indeterminable under microscope) are scarcely found. The sediment is Middle Eocene in age (SBZ 17 in the sense of Serra-Kiel et al. 1998), shallow-water, damages of tests indicates that they were found within the reach of wave activity.

Pebble 2 (Pl. I, Figs. 3-4) is not very different in petrographic composition from pebble 1 (nummulitic sandy rudstone), does not contain extraclasts, but organic remnants are more frequent. An interesting phenomenon is drilling of nummulite tests and filling up of cavities originated this way with chalcedony. The association of larger forams is formed by: *Nummulites puschi* D´ARCHIAC, *N. perforatus* (MONTFORT), *N.* cf. *semicostatus* (KAUFMANN), *N.striatus minor* D ´ARCHIAC et HAIME, *N.* aff. *parvus* (PREVER), *Assilina schwageri* (SILVESTRI), *Discocyclina discus* (RÜTIMEYER) and *Discocyclina* sp. Fragments of coralline algae, lamellibranchs, brachiopods, segments of crinoids, worm tubes are also present, smaller forams are rare (rotalid, miliolid and agglutinate forms). Complete absence of planctonic forms in the association testifies to shallow-water nearshore sedimentation, frequent damages of tests to wave activity. The pebble is Middle Eocene in age (SBZ 17).

Pebble 3 (Pl. I, Figs. 5-6): Nummulitic sandy packestone containing clasts of quartz, carbonates of average size 0.10 mm. The cement is carbonate with frequent coatings of Fe-oxides. Scarcely boring of nummulite tests and filling up of the cavities with chalcedony is visible. The association of larger forams is formed by: *Nummulites anomalus* DE LA HARPE, *N.* aff. *parvus* (PREVER), *N. perforatus* (MONTFORT), *N. semicostatus* (KAUFMANN), *N. striatus minor* D´ARCHIAC et HAIME, *Assilina schwageri* (SILVESTRI), *Discocyclina* cf. *sella* D´ARCHIAC and *Discocyclina* sp. Very often there are fragments of coralline algae (up to 0.5 mm diameter), cross sections of cyclostomate and cheilostomate bryozoans, lamellibranchs, ostracodes, crinoides are rare, worm tubes, from smaller forams rotalid, miliolid and agglutinate forms are also present. The only cross section belongs to a planctonic globigerinid form. The predominating flost tests of *Assilina schwageri* (SILVESTRI) testify to a somewhat deeper environment of origin than in preceding pebbles, but the abundant debris of coralline algal thaluses is an evidence of proximity of an environment with intense wave activity. As to age, the pebble does not differ from preceding ones (SBZ 17).

Pebble 4 (Pl. II, Fig. 1): Nummulitic sandstone formed by fragments of quartz and carbonates 0.10-0.15 mm in size, in the carbonate cement coatings of Fe-oxides are not rare. The association of larger forams is formed by: *Nummulites* cf. *puschi* D´ARCHIAC, *N. perforatus* (MONTFORT), *N. semicostatus* (KAUFMANN), *N. striatus minor* D´ARCHIAC et HAIME, *Assilina* sp. Calcareous algae are crushed, damaged are also shells of cyclostomate bryozoans, lammelibranchs, crinoid stems. From smaller forams, besides rotalids and miliolid forms, also the sessile *Acervulina linnearis* HANZAWA is found. The sorted clastic material, absence of discocyclines and on the contrary, the presence of nummulites with thick solid tests indicate a shallow-water environment within the reach of wave activity. Age - Middle Eocene (SBZ 17).

Pebble 5 (Pl. II, Figs. 2-3): Nummulitic sandy rudstone. From clasts mainly fragments of quartz and carbonates of size 0.05-0.15 mm are represented. In the carbonate cement precipitations of Fe-oxides are found. Remarkable is the deformation of embryonal parts of some nummulites, which must have taken place still during life and could have been caused by oscilations of some environmental factors (temperature, salinity etc.). The association of larger forams is formed by: *Nummulites perforatus* (MONTFORT) (in great number, both generations), *N. striatus minor* D´ARCHIAC et HAIME, *N.* cf. *semicostatus* (KAUFMANN), *Assilina schwageri* (SILVESTRI) and *Discocyclina* sp. Small fragments of coralline algae, fragments of cyclostomate bryozoans, lammelibranchs, crinoid stems are also present, from smaller forams sessile *Acervulina linnearis* (HANZAWA) is found. The rock formed in shallow-water environment in the Middle Eocene (SBZ 17).

Pebble 6 (Pl. II, Fig. 4): Nummulitic sandstone formed by angular fragments of quartz and carbonates (0.08-0.15 mm), very often are small fragments of coralline algae. The cement is carbonate. The association of larger forams is poorer and formed by: *Nummulites perforatus* (MONTFORT), *N.* cf. *semicostatus* (KAUFMANN), *N. striatus minor* D´ARCHIAC et HAIME, fragments of lamellibranchs are also found, rotalid forams are scarce. The debris of coralline algae again testifies to a shallow-water environment within the reach of wave activity. Age- Middle Eocene (SBZ 17).

The data on localisation of the sample, which from Kamenica/Torysa r. was evaluated by Vaňová (in Nemčok & Vaňová 1977), are not known. Its association is not differing from that found in pebbles 1 to 6. The

Plate I

Fig. 1 – Nummulitic sandy wackestone with cross sections of tests of *Nummulites puschi* D´ARCHIAC and *Discocyclina sella* (D´ARCHIAC). Kamenica, pebble 1, thin section. 7; Fig. 2 – Nummulitic sandy wackestone with cross sections of tests of *Nummulites puschi* D´ARCHIAC. Kamenica, pebble 1, thin section 3; Fig. 3 – Nummulitic sandy rudstone with cross sections of tests of *Nummulites perforatus* (MONTFORT), *Nummulites* sp. and *Discocyclina discus* (RÜTIMEYER). Kamenica, pebble 2, thin section 1; Fig. 4 – Nummulitic sandy rudstone with cross sections of tests of *Discocyclina discus* (RÜTIMEYER), *Nummulites striatus minor* D´ARCHIAC et HAIME and *Nummulites* sp. Kamenica, pebble 2, thin section 6; Fig. 5 – Nummulitic sandy packestone with cross sections of *Nummulites striatus minor* D´ARCHIAC et HAIME, *Assilina schwageri* (SILVESTRI). Kamenica, pebble 3, thin section 1; Fig. 6 – Nummulitic sandy packestone with cross sections of tests of *Nummulites perforatus* (MONTFORT), *N.* aff. *parvus* PREVER and *Assilina schwageri* (SILVESTRI). Kamenica, pebble 3, thin section 5. All figures magnif. 10x. Photo by the author.

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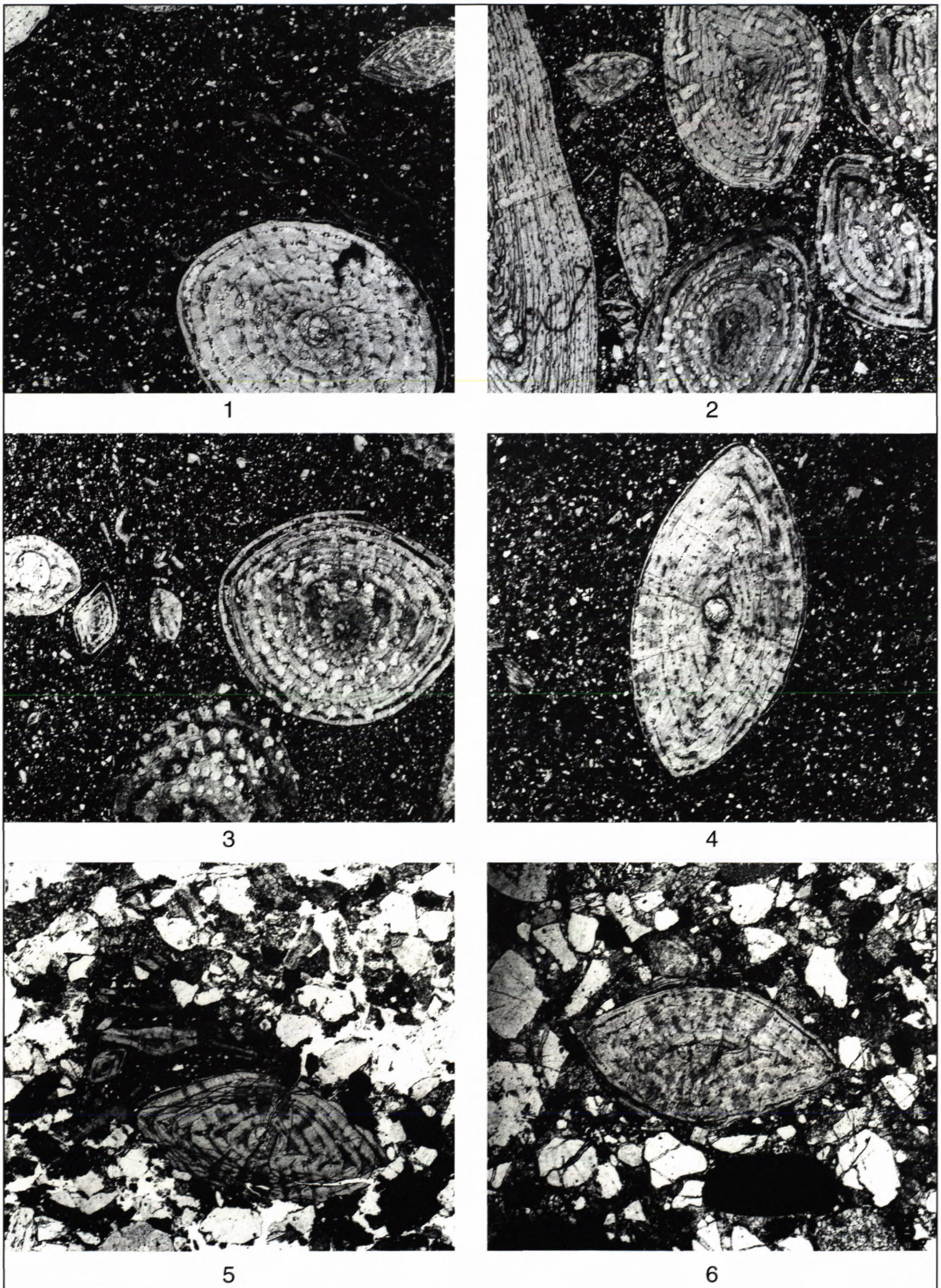

partial silicification of nummulites and *Rotalia* by quartzine at the locality Stránske (Rajec basin) was mentioned by Mišík (1995, p. 158).

Borehole Lipany-6

While the borehole Lipany-1 was published also with evaluations of larger forams (Vaňová in Leško et al. 1983), the data on borehole Lipany-6 have not been published. The author had available samples from depth of 2369 to 2396 m. There is indubitably the Šambron Member. The rock is formed by fine grained conglomerates to breccias with clasts of size up to 15 mm (scarcely also more) with variegated composition: quartz, crystalline rocks, various carbonates (among them Cretaceous marly limestone). The cement is formed by finer grained fraction. Organic remains are very scarce. In Pl. II, Fig. 5 a clast of sandy limestone with cross sections of tests of *Nummulites perforatus* (MONTFORT) and *Assilina schwageri* (SILVESTRI) is seen. Isolated tests of *Nummulites perforatus* (MONTF.) in Pl. II, Fig. 6, *N. puschi* D´ARCHIAC and *Discocyclina* sp. are also found.

These larger forams are of Middle Eocene age and were indubitably redeposited into the Šambron Member from the Borové Formation.

Conlusions

In the Paleogene of the Subtatric Group between the Tatra Mts. and Sabinov associations of larger forams of Middle Eocene age were found:

1. in situ - Veľká Kýčera near Vyšné Ružbachy, borehole Lipany-1,
2. in blocks in the Pucov Member - Ždiar,
3. in pebbles in the Šambron Member - Kamenica, borehole Lipany-6,
4. isolated tests, redeposited into the Šambron Member - boreholes Lipany-1, Lipany-6, PU-1 Šambron, Jakubovany, Šarišské Dravce, Dlhý potok brook, Milpoš.

The association formed by the species *Nummulites perforatus* (MONTFORT), *N. puschi* D´ARCHIAC, *N. striatus minor* D´ARCHIAC et HAIME, *Assilina schwageri* (SILVESTRI) , *Discocyclina discus* (RÜTIMEYER), according to latest dating (Shallow Benthic Zones - see Serra-Kiel et al. 1998), belongs to the SBZ 17 of Middle Eocene - Bartonian age with range of time 38 - 41 mil. years. The frequent presence of the association in the region between the Tatra Mts. and Sabinov testifies to the fact that there the Borové Formation was not rejuvenated in direction to the east, but sedimented in an approximately equal time interval including the SBZ 17 (38 - 41 mil. years), i. e. in the upper part of the Middle Eocene.

The presence of *Nummulites puschi* D´ARCHIAC and absence of larger assilines *Assilina exponens* (SOWERBY)) is typical of the Borové Formation at the northern Tatra Mts. slope (so called "Tatric Eocene" sensu Bieda 1963). Therefore it is necessary to suppose that the Paleogene of the Subtatric Group between the Tatra Mts. and Sabinov is the continuation of this northern strip of the "Tatric Eocene".

The different ages of the Borové Formation south of the Tatra Mts. are either a result of gradual flooding of the territory much dissected in morphology south of the Tatra Mts. or of distinct tectonic unrest.

Very frequent redepositions of larger forams tests from the Borové Formation into the Šambron Member are an evidence of intensive disintegration of the Borové Formation in the time of the Šambron Member deposition. As a consequence of sinking sea level throughout the Upper Eocene partial uncovering of the Borové Formation and its erosion could have taken place in that period, but erosion of the Borové Formation could also have been a result of tectonics.

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Plate II

Fig. 1 – Nummulitic sandstone with cross sections of *Nummulites perforatus* (MONTFORT) and *N. striatus minor* D´ARCHIAC et HAIME. Kamenica, pebble 4, thin section 2; Fig. 2 – Nummulitic sandy rudstone with numerous cross sections of tests of *Nummulites perforatus* (MONTFORT), both generations. Kamenica, pebble 5, thin section 5; Fig. 3 – Nummulitic sandy rudstone with cross sections of *Nummulites perforatus* (MONTFORT) and *N. striatus minor* D´ARCHIAC et HAIME. Kamenica, pebble 5, thin section 3; Fig. 4 – Nummulitic sandstone with cross section of test of *Nummulites perforatus* (MONTFORT). Kamenica, pebble 6, thin section 4; Fig. 5 – Fine grained conglomerate, in the middle a fragment of sandy limestone with cross sections of tests of *Nummulites perforatus* (MONTFORT) and *Assilina schwageri* (SILVESTRI). Borehole Lipany-6, depth 2396 m; Fig. 6 – Fine grained conglomerate with cross section of redeposited test of *Nummulites perforatus* (MONTFORT). Borehole Lipany-6, depth 2396 m. All figures magnif. 10x. Photo by the author.

map of Popradská kotlina basin, Hornádska kotlina basin, Levočské vrchy Mts., Spišsko-Šarišské medzihorie depression, Bachureň Mts. and Šarišská vrchovina highland 1:50 000. MŽP SR – Geologická služba SR, Bratislava.

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Jurassic of Silicicum

RAKÚS MILOŠ[1] and SÝKORA MILAN[2]

[1]Geological Survey of Slovak Republic, Mlynska dolina 1, 817 04 Bratislava, Slovak Republic
e-mail: rakus @gssr.sk
[2]Faculty of Natural Sciences of Comenius University, Department of geology and Palaeontology, Mlynska dolina, pav. G, 842 15, Bratislava, Slovak Republic

Abstract: The paper describes the particular occurrences of Jurassic of Muráň and Stratená nappes; and Silicicum nappe itself. The aim of the paper is to provide the complete information about lithostratigraphy, paleogeography and geodynamic development of Silicicum in the Jurassic time.

Unlike the surface distribution of the Triassic rocks, the Jurassic sediments are preserved only rudimentarily due to of long-term erosion. Despite of that fact the Jurassic sediments provided valuable information in understanding of the geodynamic development of Silicicum during Jurassic.

Unlike the majority of paleogeographic regions in the Western Carpathians, the Jurassic cycle is transgressive and lies with bigger or smaller hiatus on the Norian limestones (Tesná skala rock, Geravy, Bleskový Prameň, etc.). The basal members of Liassic are characterized by various facial developments of limestones that often included clasts of Triassic limestones. The other typical mark of the Silicicum Jurassic is the presence of neptunian dikes that can reach deep underlying Norian limestones (Biele Vody, Bleskový Prameň). The breccia development continues till the Middle Liassic, the clastic material is represented not only by the Triassic limestones, but by the proper Liassic limestones as well (Bleskový Prameň).

In the basinal parts (Bohúňovo) the Jurassic cycle is gradually developed from the late Triassic and unlike the elevated regions the basinal sediments of the Allgäu formation where calci-turbidite intercalations are also present.

The lower part of Middle Jurassic is characterized by the last important deposition of coarse clastics (Bohúňovo formation) and is represented by olistostrome, which material originates mainly from the Liassic limestones. Clasts of dark radiolarites are occasionally present as well (Bleskový Prameň). The upper Middle Jurassic consists mainly of radiolarites, that represent the maximal deeping. The overlying Oxfordian/ Kimmeridgian sediments are rarely presented and they have pelagic character. The deposition cycle ends by these sediments and because of closing the neighbouring Meliaticum domain the area of Silicicum is structured into a system of nappes. The new one and simultaneously the last sedimentation cycle is Tithonian (limestones with Clypeina jurassica) that definitely ends the Jurassic sedimentation in Silicicum.

The paper describes the fauna of ammonites that enabled precise stratigraphic classification of several facies of the Silicicum Jurassic.

Key words: Western Carpathians, Jurassic, lithostratigraphy, ammonites

Introduction

In comparison with other tectonic units of the Western Carpathians, the Jurassic sediments of the rear part of the Inner Carpathians are preserved only rudimentarily (with respect to the superficial distribution of the Triassic sediments). This so-called general lack of the Jurassic sediments is due to the long-term erosion (minimally from the lower Cretaceous) and to originally smaller thickness of the Jurassic sediments.

Dominant presence of Paleozoic and Triassic in this region led to obvious polarisation of the investigation effort and Jurassic was studied only marginally, what is confirmed by the little number of papers. Insufficient information about Jurassic of this region caused insurmountable obstacles in reconstruction of its paleogeographic and geodynamic development. The fact that Jurassic is the last stratigraphic record of the layer succession of strata connected to the Triassic stage of development was underestimated. As we can find in the following, the Jurassic sediments end the sedimentary cycle in this part of the Western Carpathians, what has special importance in evaluation of the geodynamic development of the region.

We can state that the last few years brought turnover. The widespread utilisation of micropaleontologic methods (mainly radiolarians and palynomorphs) enabled stratigraphic dating of deep water sediments, particularly of the Meliaticum, and their attribution to Jurassic, what has great importance in understanding of the geology of the region.

Considering the sufficient reviewing of the Jurassic history of this region in the past (Bystrický, 1960, 1964,

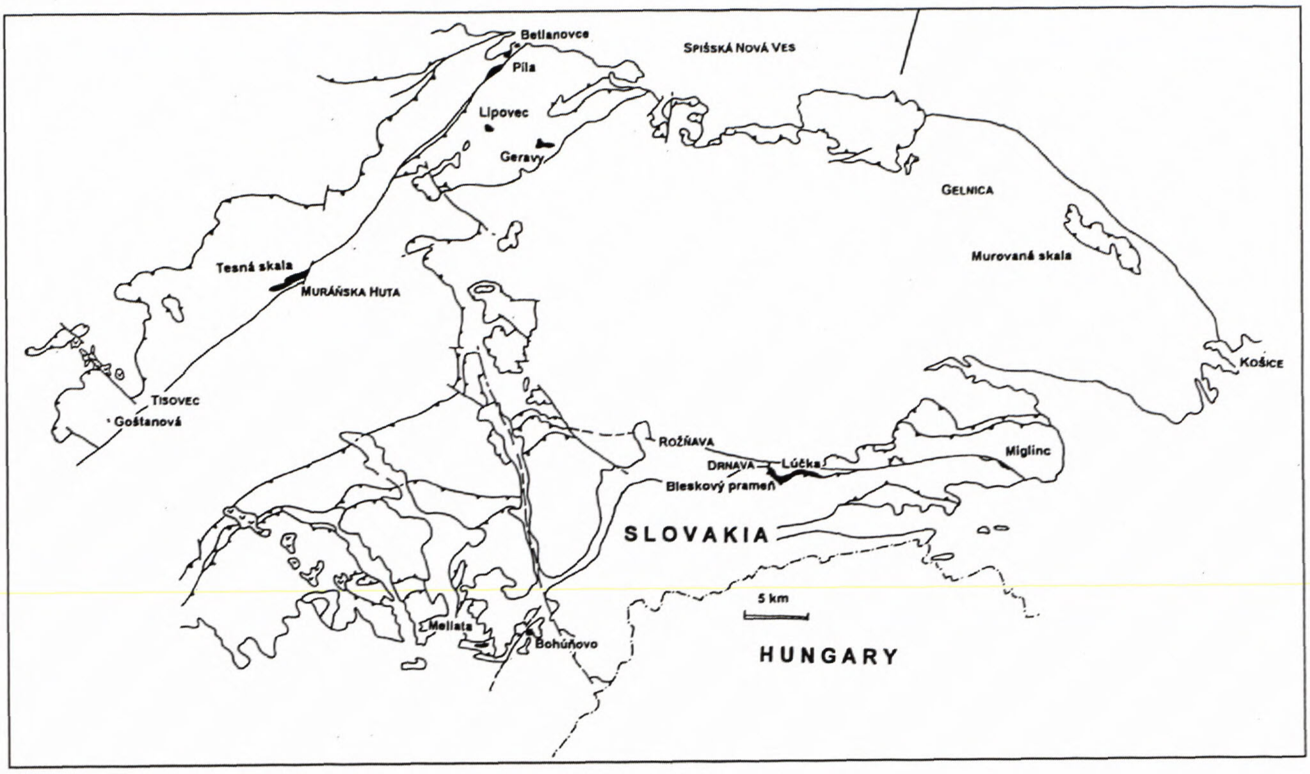


Fig. 1 Schematic map of Jurassic outcrops of Silicicum in the Inner Carpathians

1973, Kollárová-Andrusovová, 1966 and Rakús, 1967), we shall not deal with it in detail.

The aim of this paper is to provide summarizing information about lithostratigraphy, paleogeography, and geodynamic development of Jurassic in rear parts of the inner Carpathians taking into account all the present knowledge.

LOCALITIES AND LITOFACIES DESCRIPTION

Jurassic of Muránska planina plateau

Jurassic of the Muráň nappe was discovered by Bystrický in 1959 during the compilation of general map. In 1952 Biely refined its lithostratigraphy and stated that Jurassic is represented only by Lias. Jurassic of the Muráň nappe occurs at narrow belt in core of Tesná Skala syncline, northward of Muránska Huta (fig. 1).

Locality Tesná Skala, northward of Muránska Huta (fig. 1, 2)

The Jurassic or Liassic rocks are only poorly resistant against weathering, therefore their exposures are insufficient and the tracking of their lithological succession is very restricted. The best exposures occur in the forest path cut near the forest nursery where the following profile can be observed (from bottom to top) (fig. 2):

1) Light grey, occasionally brownish, fine-grained, thick-banked limestones are well correlated with the Dachstein formation. Microfacially they are grainstones – biointrasparitic limestones, where micrite intraclasts of irregular shapes are the dominant component. Then there were found pelsparites, with an amount of spheroidal bodies (about 0,1 mm) probably of bioclastic origin.

Biocomponent is represented by „glomospiroid" foraminifers, fragments of lamellibranchiates and punctate brachiopods, echinoid spines and rare coprolites (*Parafavreina sp.*). Compared to other localities in the Muráň nappe we consider these limestones as Norian.

The Skalka limestones (Michalík, 1977; Michalík and Gaždzicki, 1983) considered as Rhaetian, were not found here. Similarly, the Kössens member described by Biely (1962) was not found in this profile, although its occurrences are nearby (about 300 m NW from profile on northern edge of the syncline). Missing of the facies mentioned above can be explained by erosion during the lowest Liassic-Hettangian. This explanation is confirmed by the fact that the top parts of the Dachstein limestones bear distinct traces of alteration, and small neptunian dikes filled by brownish-red laminated micrite limestone occur there. The surface of the Dachstein limestones on the contact with the Liassic crinoidal limestones is covered by thin haematite crusts with flat chlorite concretions and it has hardground character. Absence of the Skalka limestones as well as Kössen memberlayers emphasizes the transgressive character of Liassic.

2) Grey to greyish-brown, sometimes pink crinoidal limestones – crinoidal biomicrites – **Hierlatz limestones** directly overlying the Dachstein limestones. Lithologically they are grey, mostly light grey, or brown, in upper parts pinkish, fine crinoidal sometimes banked (up to 20 cm) limestones.

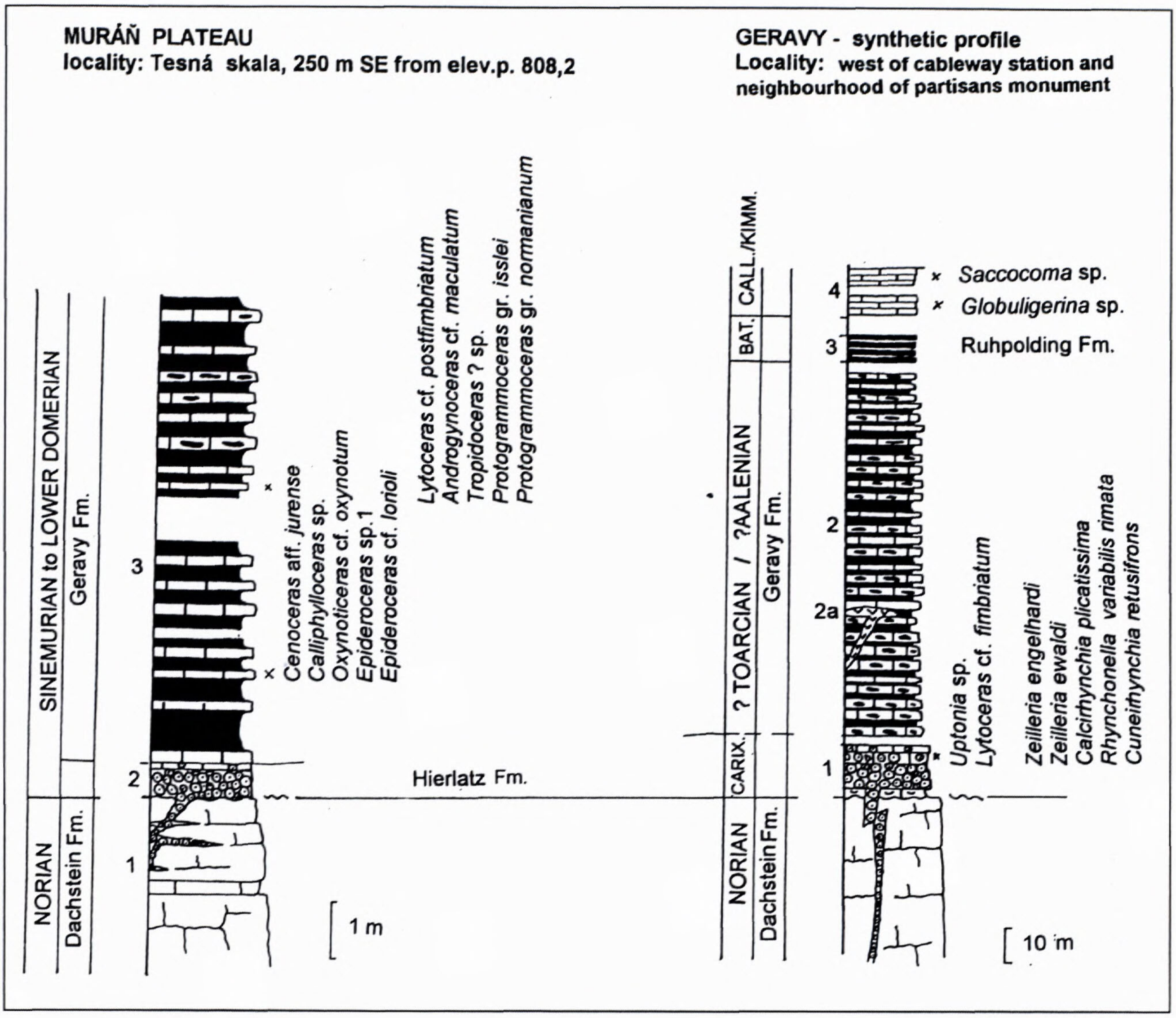


Fig. 2

Micrite matrix contains the segments of crinoids, slightly rounded fragments of punctate brachiopods („*Terebratula*“), fragments of lamellibranchiates, ostracods and Bryozoa. Rarely there occur foraminifers: *Lenticulina* sp., *Nodosaria* sp. Moreover, there are lithoclasts of Triassic carbonates – pelsparites , as well as foraminifer limestones. At Geravy, where these limestones have a some what more varied development, Mahel' described presence of cherts (l.c.: 65); however we were not successful in finding them.

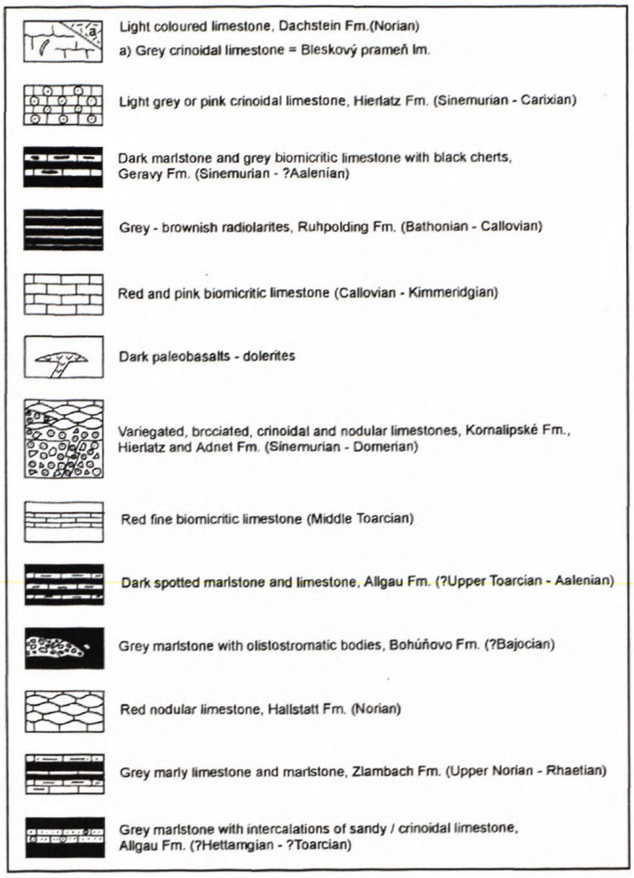
Thickness: The measurable thickness is very low and it varies from 30–50 cm to about 5 m (near the forest nursery). At Geravy and Lipovec it could reach up to 10 m (estimation).

Stratigraphic range: up to now it has not been determined directly. Based on the brachiopod fauna (Geravy site) and position in basement of the Geravy formation, we assign these limestones to Sinnemurian s.l., most probably to Lotharingian.

3) Grey fine-grained limestones are directly overlying of crinoidal limestones. Microfacially they are micrites with rare fine admixture of clastic quartz and fine scales of mica. Relatively abundant occurrences of authigenic plagioclases are observed. Biocomponent is represented by silicisponge spicules; spherical calcified radiolarians and sporadical small (less than 0,1 mm) peloid grains. Authigenic pyrite is abundant.

In overlying direction these limestones gradually pass into several tens metres thick complex of dark-grey non-spotted marlstones with intercalations of grey banked (5-10-18 cm) biomicrite limestones – the Geravy formation (see description of Jurassic in Geravy). In debris (towards the well intercepted on the lower meadow) black silicites occur as well (spongolites). (Note: the term „Allgäu formation“ we use in quotation marks because we want to emphasize certain difference from the typical facies. This difference consists in non-spotted character and higher content of intercalations of more or less crinoidal limestones.)

Amidst of the Liassic strip, near by the elevation point 808,2 m, Biely found (ex-situ) a cephalopod fauna in grey more or less crinoidal limestones. The limestones are bio-



Explanations to text-figures 2, 5, 8, and 9

sparites with a plenty of crinoid segments, sea urchin spines, fragments of brachiopods and pelecypods and spicules of silicisponges (Pl. 8, Fig. 3). Foraminifers are represented by *Dentalina* sp., *Lenticulina* sp., *Nodosaria* sp. *and Involutina liassica* Jones. Intraclasts and clastic silty quartz were identified less often.

We have determined these Cephalopoda:

Cenoceras aff. jurense (QUENSTEDT), *Calliphylloceras* sp., *Lytoceras* cf. *postfimbriatum* PRINZ, *Oxynoticeras* cf. *oxynotum* (QUENSTEDT), *Epideroceras* sp.1, *E.* cf. *lorioli* (HUG), *Tropidoceras* ? sp., *Androgynoceras* cf. *maculatum* (YOUNG & BIRD), *Protogrammoceras* gr. *isslei* (FUCINI), *P. gr. normanianum* (d'ORB.).

This association indicates Lotharingian (zone Oxynotum /Raricostatum Zone), Carixian (Davoei Zone), up to Lower Domerian (Stokesi Zone). Upper members of Jurassic formation have not been found yet at the Tesná Skala locality.

Jurassic in Goštanová (fig. 1)

The Jurassic sediments were plotted for the first time in the map of the Slovenské Rudohorie Mts. (Klinec, 1976). However, the rocks ranged here to Jurassic, actually belong to Late Triassic. Lately this area was investigated by Vojtko (1999), who confirmed the occurrence of Jurassic in Goštanová, which form here filling of neptunian dikes and does not form superficially bigger occurrences.

Jurassic is represented by dark-grey organo-detritic limestones (packstones). They are composed mainly of segments of echinoderms (crinoids, sea urchins), fragments of lamellibranchiates and brachiopods. The ostracods (with thin and thick tests) occur very often. Uniserial foraminifers of genus *Nodosaria* and planispirals of genus *Ammodiscus* are presented seldom. Dr. Soták in Vojtko (1999) determined the following species here: *Ammodiscus incertus* (d'ORB.), *A. multiinvolutus* REITLINGER and *Nodosaria nitidana* BRAND. Some tests of lamellibranchiate are drilled by algae. Limestone contains rarely plastically deformed intraclasts of mudstones – micrites and peloids. Clastic quartz of fine - grained sand size is also one of the components present (less than 1 %). Beside the primary components, authigenic plagioclase and pyrite occur and some of the bioclasts are silicified.

According to the lithofacial character the limestones described above can be classified as Liassic.

Jurassic of the Vernár belt (fig.1)

At the beginning it should be stated that majority of the Jurassic occurrences in so-called Vernár belt (only with one exception) have a unclear structural position with respect to the older members of the bed sequence. In reality, there are block occurrences that can represent megaclasts of Pre-Eocene sedimentary cycle - ? Late Cretaceous.

In the northern vicinity of the Píla village near Hrabušice Maheľ (1957) described two Jurassic occurrences. In both cases there are small, isolated occurrences formed by red to redish-violet more or less crinoidal limestones with abundant tiny lithoclasts (up to 3 mm) of yellow carbonates.

The first occurrence is situated NW from the elevation point 676,2 m where light coloured to whitish thick-banked Dachstein limestones are present in small exposure. Microfacially there are packstones – grainstones with *Tetrataxis* cf. *nana* KRISTAN-TOLLMANN, *Permodiscus* sp. and *Angulodiscus* sp.

Overlying and in overlain and lateral continuation, red, partly re-crystallised fine-grained more or less clayey limestones are present in debris. Microfacially they are micrites with seldom and poorly preserved radiolarians and intrapelsparite with rare bioclasts – ostracods and little lamellibranchiates.

The second occurrence is situated about 650 m SE from the elev. p. 654,8 m. In small discontinuous exposures (block debris) grey fine-grained limestones with small dikes composed of red micrite carbonates occur.

Overlying them there is debris consisting of greyish-red, redish-violet crinoidal limestones with abundant, unrounded lithoclasts (up to 3 mm) of yellow carbonates (Pl. 8, Fig. 1, 2). They contain lithoclasts, fragments (usually of micrite limestones and clastic quartz). Bioclasts are represented mainly by fragments of crinoidal segments and echinoderms, fragments of punctate brachiopods, as well as fragments of hydrozoans. Rarely *Nodosaria* sp. and fish teeth were found. Among lithoclasts-pelmicrites, pelsparites, biosparites and oosparites were identified that are probably of Triassic age. Quartz is monocrystallic and undulate. Clasts are rounded and unsorted. According to the particle size the rock is at psephite-psammite boundary and it can be considered as residual sediment (lag deposits). Mahel' (1957:92) described a fauna of brachiopods in them, which indicates a Lotharingian age:

Calcirhynchia plicatissima (QU.), *Rhynchonella deffneri* OPP., *Spiriferina alpina* OPP., *Spiriferina obtusa* OPP., *Spiriferina pinguis* ZIET., *Zeilleria engelhardti* (OPP.).

A finding (ex situ) by one of the authors (M.S.) in the Betlanovce neighbourhood showed the brown-red fine-grained limestones – packstones with fibrous microfacies. The majority of the packstone consists of fragments of thin-walled shells tests of lamellibranchiates. Except of them there are fragments of massive tests that are leached off and replaced by calcite crystals coloured by Fe-hydroxides. Further there were found: *Lenticulina* sp., segments of echinoderms, aptychi, *Globochaete alpina* LOMBARD, calcified radiolarians, ostracods and representatives of *Globuligerinidae.* A terrigenic admixture – quartz of silt size content of which is bellow 1 % occur here as well. Rarely grains of chlorite as well as bright mica were found here. Considering the presence of globuligerinids we range these limestones to Callovian-Oxfordian.

Red bioclastic limestones are the next lithotype. The most abundant components are segments of planktonic echinoderms of genus *Saccocoma*, columnaria of crinoids (seldom *Pentacrinus* type), aptychi, fragments of lamellibranchiates and brachiopod shells, ostracods (seldom) and *Cadosina* sp. Rarely clastic quartz occurs there. Clasts of re-crystallised bacterial Fe/Mn stromatolites and metha-colloid grains are one of the limestone components. Irregular cavities– fenestrae with polarity textures occur in sediments. This type is ranged to Kimmeridgian.

Jurassic of the Stratenská hornatina Mts.

As in previous regions, Jurassic occurrences are preserved only rudimentarily, and were unknown for a long time. The first information is by Mahel' (1957) who briefly described and stratigraphically classified them. In fact there are two occurrences, which despite of their relatively larger areal extension, are poorly exposed, regarding their lithology and structural position. The research of the last years enabled us to range the known facial types into a bed sequence that can be correlated, for instance, with the Muráňska Planina plateau.

Locality Geravy (fig.1, 2)

Similarly as in the Muráňska Planina plateau, the Jurassic lies transgressively on various facies of the late Triassic – Dachstein limestones, Norian in age. Transgressive relation of the Liassic crinoidal limestones can be observed in NW neighbourhood of the monument in Geravy. The crinoidal limestones occur directly overlying by light - grey to white massive limestones of the Norian Dachstein formation. In places (approximately 500 m eastward of the top station of the cableway at the forest border), the top parts of the late Triassic limestones are, on the contrary, formed by grey thick-banked grapestones (SMF 17) with *Aulotortus* sp., which would indicate Norian age.

1) As the lowest member of the Jurassic layer succession the **Hierlatz limestones** are considered. They are grey, light-grey, occasionally greyish-brown to redish biomicrites with varying share of crinoidal segments, thus locally they are crinoidal sparites. These limestones lie directly on Dachstein limestones (westward of the monument in Geravy) or they penetrate deeply (up to 120 m) through a system of neptunian dike into late Triassic limestones (gamekeeper´s cottage eastward of Biele Vody, personal information from Dr. Havrila, 1995). Microfacially there are mainly biomicrites - packstones, and also crinoidal sparites. There are relatively abundant cross sections of foraminifers – *Lenticulina* sp., *Frondicularia* sp., *Trocholina* sp. *and Neoangulodiscus carinatus* LEISCHNER (in Kullmanová 1963).

From redish varieties of the limestone in the vicinity of the memorial Mahel' (1957:65) mentioned the following brachiopods:

Zeilleria engelhardti (OPP.), *Zeilleria ewaldi* (OPP.), *Calcirhynchia plicatissima* (QU.), *Rhynchonella variabilis rimata* GEYER, *Cuneirhynchia retusifrons* (OPP.), (revised by Dr. J. Pevný). The stratigraphic range is Lotharingian – Domerian.

Poorly preserved ammonites originate from greyish varieties of the limestones:

Lytoceras sp. (*Lytoceras* gr. *fimbriatum* (SOW.), *Uptonia* ? sp., which would indicate the Carixian, probably Jamesoni Zone.

2) As the next member of strata there is the formation of the dark-grey to black, clayey-calcareous shales with banks (5-10-15 cm) of fine sandy slightly-crinoidal limestones of the same colour and with nodules of black silicites = **Geravy formation – new name**.

Type locality: Geravy, gorge under the bottom station of the ski lift.

Informal names: black and dark-grey clayey shales (Mahel', 1957: 64).

Lithology: formation of black clayey calcareous shales with layers - banks of fine-sandy slightly-crinoidal limestones of the same colour. Limestones contain nodules of black cherts.

Microfacially they can be characterized as biomicrites -packstones. Fine grain sand to silt size bioclasts consist of fragments of echinoderm segments, chambers of nodosarid and planispiral foraminifers, ostracods, tiny calcified spicules of porifera and radiolarians. Silt size clastic quartz is also present. Except of this type, there occur also more marly varieties resembling "fleckenmergel" with low bioturbation (? *Chondrites*).

As particularity we mention finding of pieces of paleobasalt – dolerites affected by chloritisation of mafic minerals! Because of their scattered occurrences, we did not succeed in finding out the relation to neighbouring environment.

Thickness: it is very hard to determine the thickness because of their poor exposure. It is estimated to several tens metres.

Stratigraphic range: the attribution of this formation at type locality is not yet known, although there is no doubt about its Liassic age. Maheľ (1957 : 64) described in black shales: *Spiriferina alpina* OPP., which is known from Early and Middle Liassic. In Muránska Planina plateau the association of ammonites comes from this formation which age is Lotharingian - Carixian, what is in good harmony with occurrence of *Sp. alpina* in Geravy. With respect to the fauna content we prefer Middle/Late Liassic age, but it is not excluded that the formation of black shales reaches into Early Dogger as well.

3) About 100 m SE from the monument in the forest road cut the thin lens (observable thickness 0,5 – 1 m) of grey-brown radiolarian rocks occurs, from which we obtained only indeterminable radiolarians ranged to Dogger (?Bajocian – Bathonian).

4) As the stratigraphically highest proved member of the Jurassic succession the red biomicrites can be assigned, which occur in debries, eastward of the monument. Microfacially there are packstones with fibrous-echinoderm microfacies. Foraminifers occur there relatively often: *Tetrataxis* sp., *Lenticulina* sp., *Nodosaria* sp., *Ophtalmidium* sp. *and Globuligerina* sp. (Pl. 8, Fig. 4). Clastic quartz and small oncoides occur quite rarely. Based on the presence of genus *Globuligerina* (and absence of genus *Cadosina*) we range the limestones to Callovian.

Kullmanová (1963) mentions the occurrence of pink fine-grained massive limestones with *Saccocoma sp.* what suggests presence of Kimmeridgian sediments. We point out that we were not successful in repeating this finding.

Locality Lipovec (fig.1)

According to Maheľ (1957:64) the situation here is similar to that in Geravy. The present terrain exposure does not enable direct determination of the bed sequence. It seems that similarly as in Geravy the bulk rock mass is formed by dark-grey to black clayey-calcareous shales with layers of limestones containing cherts. Bigger clastic admixture can be observed macroscopically in limestones. It consists of lithoclasts of carbonates and quartz (up to 2 – 3 mm).

At this locality Kullmanová (1963) described the presence of grey more or less crinoidal and compact limestones with nodules of brownish-grey cherts. She mentions the presence of *Involutina liassica* (JONES) *and Trocholina* sp. in limestones what indicates Lias age. Stratigraphically higher members as Lias were not found here.

Jurassic of Slovenský Kras

In comparing with the Jurassic occurrences that were described in the previous part, the Jurassic of Slovenský Kras is much better known, thanks to more complete and better preserved succession.

The Jurassic sediments occur mainly in SE neighbourhood of Drnava, on southern foothills of Drienkova Hora near by the well-known Late Triassic locality Bleskový Prameň (fig. 3, 5). From this place, they can be traced from the upper part of Vrbovy Potok brook towards Kornalipske Sedlo pass, from which they stretch in a narrow strip to Kováčová and Lúčka villages.

The second, smaller Jurassic occurrence is in the Miglinc valley, where the exposure is very poor and succession is incomplete.

Except of these localities, the last known Jurassic occurrences in our territory are close to Bohúňovo and southward of Meliata near the northern margin of the Muráň River canyon.

Jurassic near Bleskový Prameň (figs 1, 3, 4, 5)

This locality is known from the past by its abundance of the Late Triassic fauna of Norian age, which is described in several monographs (Sturzenbaum, 1879, Bittner, 1890, Mojsisovics, 1896, Kollárová & Kochanová, 1973 and Siblík, 1967).

The first reference about the Jurassic red crinoidal limestones is by Sturzenbaum (1879). Although this locality was later several times mentioned, these written references did not bring a contribution to knowledge of the succession and Jurassic stratigraphy. However, we should mention the contributions of Andrusov & Šuf (1936) and Andrusov (1953) in which the authors described and figured the first fossils confirming the Liassic age.

Remarkable change is dated to 60-ies, when Bystricky (1960 a 1964) published important papers, in which he defined not only the succession, but he also identified the transgressive character of Jurassic on Drienkova Hora Mt. The following two papers from that time have paleontological character and specify the stratigraphic range of some facies (Kollárová-Andrusovová, 1966 and Rakús, 1967).

The papers published in 70-ies summarized only information known so far (Bystrický, 1970 and Mello in Bystrický, 1973). The last publication about this locality was recently issued and has dealt with stratigraphy of lithoclasts of Middle Jurassic (Sýkora & Ožvoldová, 1996).

Despite of undoubted increase information about Jurassic of this locality the question of succession as well as stratigraphic range of particular lithofacies was not solved. These problems result mainly from varied quickly changing lithology of limestones in short distance, plenty of little faults and in insufficient precision of the stratigraphy. The profile that we present in this paper was elaborated after several years-lasting research and it consist of several partial profiles (Roman figures in column) that were adjusted on the basis of detailed microfacial correlation and stratigraphic range of particular lithofacial

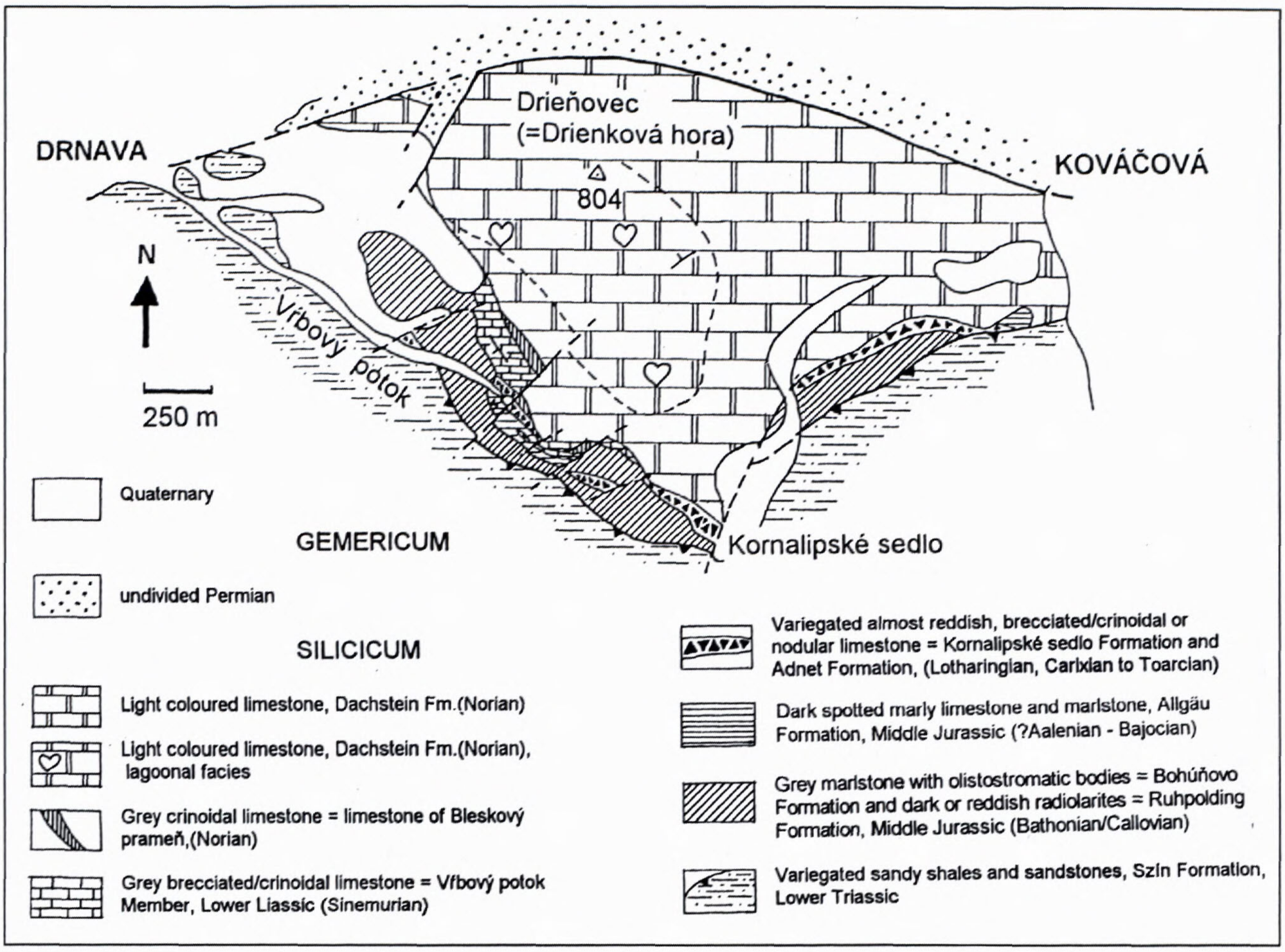


Fig. 3 Geological sketch map of Drienkova hora (after Mello, 1996 completed by author)

types. We could establish there this bed sequence of Jurassic (fig. 4).

The Jurassic basement is formed by limestones of Bleskový Prameň (= grey crinoidal biosparites with rich fauna of brachiopods, bivalves, gastropods, nautiloids (rarely) and ammonites (cf. Kollárová-Andrusovová & Kochanová, 1973, Siblík, 1967) or by **reef coral-sponge** limestones of Drienkova Hora Mt. The first type represents fore-reef facies where fauna is re-deposited and represents thanatocoenosis (Kollárová-Andrusovová & Kochanová, 1973). The above mentioned limestone types are of Norian age (Sevatian). The presence of Rhaetian stage was not confirmed! From the geological situation it is obvious that (cf. Text-fig. 3) the basal crinoidal - brecciated limestones of Liassic (= Kornalipké sedlo formation) rest on various lithofacial types of Late Triassic what emphasizes their transgressive character.

1) The oldest sediments of the Jurassic sedimentary cycle are formed by a variegated formation of crinoidal-brecciated limestones, for which we introduce a new name: Kornalipské sedlo formation (see next).

The base of the Kornalipské sedlo formation is formed by greyish-brown massive to thick-banked brecciated limestones = **limestones of Vŕbový Potok – new name.**

Limestones of Vŕbový Potok

Type locality: Vŕbový Potok near Bleskový Prameň, southward of Drienkova Hora Mt. (fig. 3).
Informal names: grey limestones (Bystrický, 1960:41); light brown to greyish brecciated weakly-crinoidal limestones (Rakús, 1967: 6).

Lithology: greyish-brown massive, occasionally thick banked brecciated limestones with variable content of detritus of crinoidal segments and lithoclasts. Lithoclasts form by various facies of Triassic carbonates, from which were identified: pelsparites with ostracods, dolomites, micrite with *Trochammina* cf. *almtalensis* KOEHN-ZANINETTI and ?*Cayeuxia* sp., grainstone with *Aulotortus* sp., mudstone-biomicrite with fibrous microfacies (similar to „Reifling type“), peloidal grainstones impregnated by hydroxides of Fe, micrite with calcified spicules of silicisponges. In the parts of the breccia there are fragments of echinoderm segments, fragments of lamellibranchiate shells and rarely Hydrozoa.

The sample BP/2 is rudstone formed by rounded bioclasts (lamellibranchiata, segments of echinoderms, *Cayeuxia sp.,* seldom foraminifers, lithoclasts of micrites and pelsparite with ostracods). In the upper part (sample BP/3) there are rather grey limestones (grainstones-

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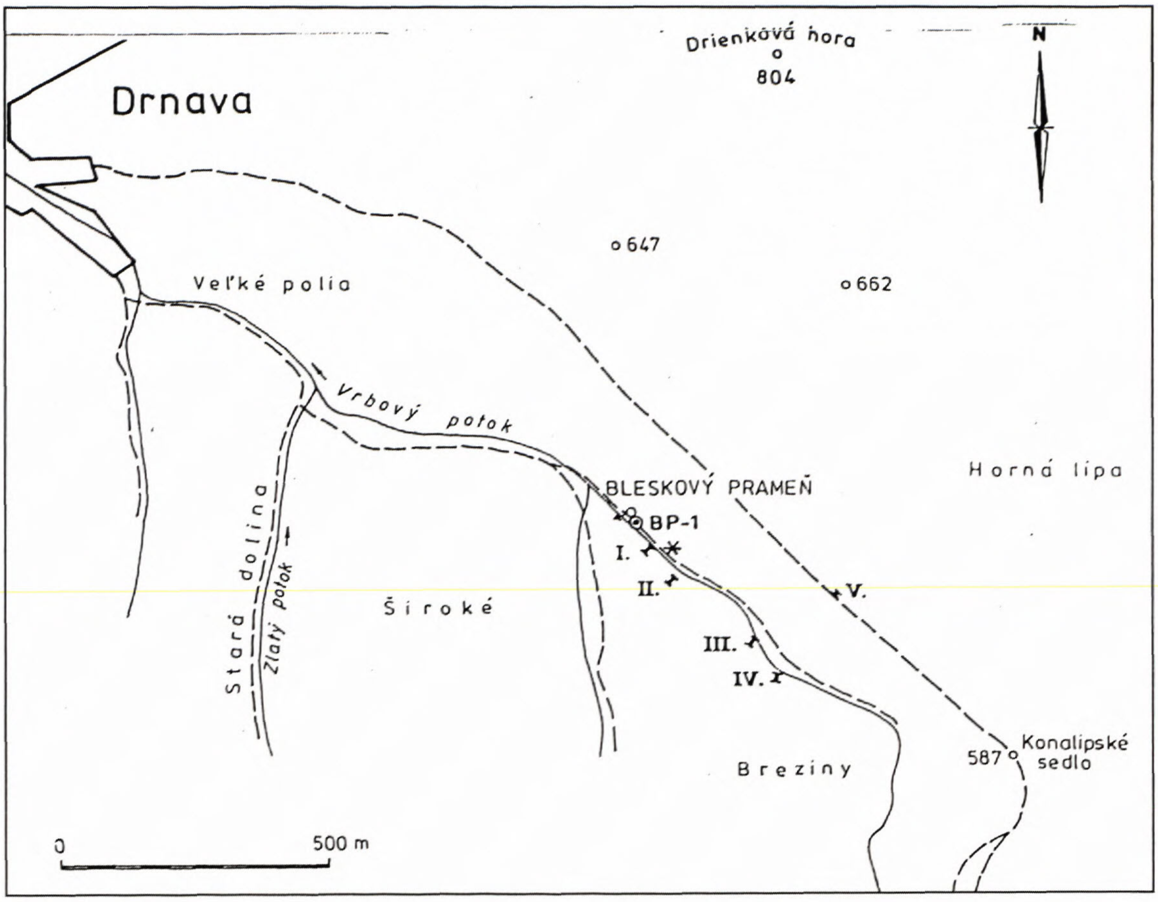

Fig. 4 Location of the partiale profiles in the vicinity of Bleskový prameň near Drnava. BP – 1 borehole, I.– V. partiale profiles.

intrabiosparites) cemented by A and B types cement. There are often fragments of cyanophycean coatings, micrite bioclasts and pellets. Abundant sediment components are lithoclasts with foraminifers: *Triasina hantkeni* MAJZON, *Permodiscus* sp., *Aulotortus* sp., *Auloconus* sp., *Variostoma* sp., *Planiinvolutina* sp. (Pl. 4, Fig. 1)

(Note: in the groove that does not exist now – a - days, on contact of limestones Norian in age with limestones described above existed a thin (up to 10 cm) layer of dark-grey marly slightly-crinoidal limestones, however their age was not determined).

Thickness: 4 m

Stratigraphic range: direct dating based on fossils has not been carried out till now. Incomplete belemnite rostra do not enable precise dating. According to their position we range them to Sinemurian.

Variegated (greyish-green, beige, pinkish and red) crinoidal-brecciated limestones with lithoclasts = **Kornalipské sedlo formation – new name.**

Kornalipské sedlo formation

Type locality: Kornalipské Sedlo pass, SE from Drienkova Hora Mt., Vŕbovy Potok brook (fig. 3).

Informal names: crinoidal and massive limestones, usually of red colour (Andrusov, 1953 : 119); grey, but mostly red crinoidal limestones and limestone breccias (Bystrický, 1960 : 41); red brecciated limestones (Rakús, 1967: 7).

Lithology: facial variety is typical for this formation. However, its bottom parts are formed mostly by greyish-green limestones, occasionally by redish-brown varieties with dark-grey limestone lithoclasts (10 x 30 cm) with silicifications. Towards the overlying parts, but laterally as well, there are transitions changes into pink to red thick coarse-crinoidal limestones of Hierlatz type with lithoclasts of grey grained limestones (Pl. 5, Fig. 1).

Thickness: up to 10 m.

Stratigraphic range: it is not confirmed directly yet. Based on its position bellow the Adnether formation of Carixian age we consider it as Lotharingian /Carixian.

Red nodular Adneth limestones: this formation is gradually developed from underlying formation, what makes difficult its strict distinction from the Kornalipské sedlo limestones. As the whole it can be designated here as „Hierlatz/Adneth formation", where several transitions exist between marginal varieties, cartographic distinction of which is not possible. We can often observe „nodules" formed by fine biomicrites, which are „drowned" in coarse-crinoidal varieties (Pl. 3, Fig. 1). Except of intraclasts, there are present also lithoclasts (10 x 20 cm) of grey fine-grained limestones where the biodetritus is formed by minute crinoidal as well as echinoderm segments. The ostracods are less presented, foraminifers of genus *Nodosaria* and *Textularia* are very rarely found. Further, minute grains of clastic quartz, flakes of light - coloured mica, authigenic pyrite and plagioklase are present.

The following fauna comes from the red limestones (Rakús, 1967):

Zetoceras zetes (d'ORB.), *Juraphyllites* sp., *Androgynoceras* sp., *Acanthopleuroceras* ? sp., *Fuciniceras* sp., *Chlamys (Velata)* sp., *Securithyris adnethensis* (SUESS), *Pentacrinus* sp. (segments, stalks and calyxes), *Passalotheutis* sp.

This fauna association refers to Carixian. The fauna found in these limestones by Andrusov & Šuf (1936) and Andrusov (1953) refers to the same age . The exception is genus *"Vermiceras"*, which belongs to Lower Sinemurian. Andrusov (cf. 1953, pl. 15, fig. A) re-determined it later to *Paltechioceras* that occurs in the Upper Lotharingian. From the Andrusov's depiction it is obvious that its preservation is very poor and we cannot exclude that it is an *acanthopleuroceratoid* form. The rich fauna that was described by Kollárová-Andrusovová (1966) at Miglinc locality in the same limestones shows almost the same age – Carixian and Early Domerian.

The above described limestone types form the filling of neptunian dikes that intersect not only the underlying brecciated limestones, but reach also deep into the Late Triassic limestones. Hydrogeological well drilled directly in Bleskový Prameň reached them in 30 m depth! Bystricky (1964) states that this type of limestones in the Kornalipské sedlo rests directly on light coloured limestones of Late Triassic.

Note: the real Adneth formation of Carixian age occurs on the Miglinc locality (see next).

4) The top parts of the Hierlatz-Adneth facies are formed by red, banked, fine-grained biomicrites with indistinct nodularity. Limestones belong to biomicrites – wackestones with fragments of Lamellibranchiata, ammonites, segments of Echinodermata and ostracods. Biodetritus is often drilled by Algae and Porifera (sample BP/6; Pl. 4, Fig. 2). The following ammonite fauna comes from these limestones (finding of Dr. J. Soták):

Dactylioceras sp., *Hildoceras sublevisoni* FUCINI.

This points to Middle Toarcian, Bifrons Zone. Although the direct contact with overlying spotted limestones is not exposed, the deposition conditions show without doubt that the "fleckenmergel" formation is overlying it normally.

5) Alteration of dark-grey calcareous claystones and banked (8, 13, 15, 18 cm) spotted limestones - "fleckenmergel" = **Allgäu formation.** Microfacially, there are mudstones with rare bioclasts of minute fragments of echinoderm segments, ostracods and pellets. In small amount the clastic quartz (silt) is present as well as aggregates of epigenetic pyrite (samples BP/7 and BP/8). Measurable thickness up to 10 m is in valley of the Vŕbový potok brook. In top parts of the formation there are stratiform nodules of dark silicites or dark aphanitic silicified limestones (Mello, 1973).

The opinions about the age of this formation were quite different (Bystrický, 1960). The last named, (l.c.: 44) based on superposition above Liassic, considered them ? as Doggerian. The finding of the nautiloid cephalopod (most probably *Cenoceras*) in this formation in the Miglinc valley is unfortunately not sufficient. Based on the investigated age of underlying limestones (Toarcian) this assignment seems to be reasonable.

6) As the next lithostratigraphic member there is the formation of calcareous claystones with irregular accumulations of carbonate breccias of debris flow type (fig. 5, Pl. 2, Fig. 2, 3) = **Bohúňovo formation – new name.**

Type locality: Bohúňovo village area, near the gas transit pipeline.

Appendix profiles: Vŕbový Potok.

Informal names: endostratigraphic breccia (Bystrický, 1964 : 78), carbonated breccia (Sýkora & Ožvoldová, 1996 : 21).

Lithology: The bulk mass of debris flow breccias is situated overlying the spotted limestones and underlying black radiolarites. Thin intercalations of breccias occur in the radiolarites as stated by Mello (1973).

The olistostrome itself consists of blocks of various sizes (from several cm3 to 3–4 m^3). Blocks and lithoclasts are usually formed by various types of limestones (Pl.4, Fig. 3 ; Pl. 5, Fig. 2), but mainly by crinoidal-brecciated limestones. They are varyously rounded, sometimes with alteration rim. Matrix of these debris flow deposits (see Sykora & Ožvoldová, 1996) is formed by calcareous claystones to clayey limestones in which lithoclasts of various sizes occur (Pl. 5, Fig. 4). There were identified the segments of echinoderms (crinoids, ophiurians, sea urchin spines). Sclerites of holothurians, fragments of lamellibranchiates (also filaments) and brachiopod are rare. Ostracods and radiolarians were found rarely. The biodetritus is not sorted according to the size. Part of the matrix is clastic quartz (silt) and mica and epigenetic pyrite. The characteristic mark of the breccia is the albitisation of lithoclasts margins. In smaller grains the albitisation usually obscures their original structure. Some of grains are not affected by this metamorphose (for instance Late Triassic grainstones). The formation of albite in carbonates is a characteristic indication of brine – carbonate interactions at temperatures of high – grade diagenesis (? 150 – 200 °C) to lower greenschist facies (? 300 – 350 °C), see Spötl et al., 1999.

The Triassic and Jurassic rocks were identified in the lithoclasts, mainly limestones, less often fragments of calcareous claystones. In the upper parts of the formation the angular lithoclasts of dark-grey radiolarites are part of the breccia!

Lithoclasts of the Triassic rocks are usually the Late Triassic limestones of Drienkova Hora Mt. type with foraminifers, lamellibranchiates, fragments of corals, gastropods and peloids. More often there are Liassic greyish to grey-pink limestones (biomicrites–wackestones) with abundant segments of echinoderms, calcified spicules of silicisponges, ostracods, foraminifers: *Ophtalmidium leischneri* KRISTAN-TOLLMANN, Ophtalmidium sp., *Involutina liassica* JONES, *Nodosaria* sp., *Lenticulina sp.* Seldom lithoclasts of spotted limestones were found. Calcareous claystones are more rare. They contain silty quartz, mica and fine organic detritus. Often

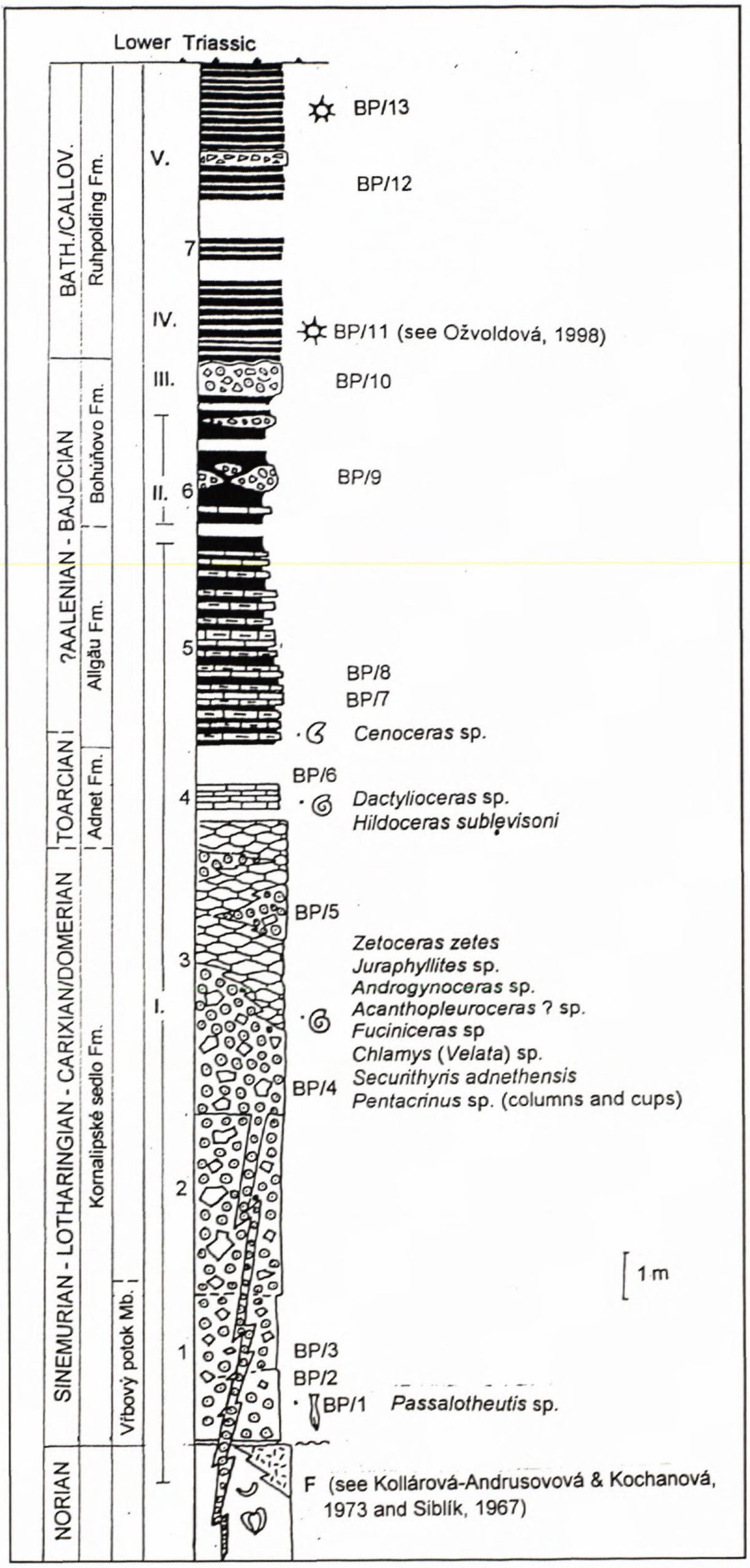

Fig 5 Bleskový prameň composite lithostratigraphic profile. Rakús, 1993

we can observe plastic synsedimentary deformations (Pl. 3, Fig. 2).

As mentioned above, the lithoclasts of blackish-grey radiolarites are also part of the breccia, although their occurrence is sporadic (Pl. 3, Fig. 3; Pl. 5, Fig. 3). In clasts of radiolarites the radiolarians were identified that are according to Sýkora & Ožvoldova (1996) (l.c. 23) of Bathonian-early Kellovian age.

In the top part of the Olistostrome formation there is a thin (0,5 – 1 m) layer of green crinoidal limestones (? calciturbidite) with clasts of biomicritic limestones (Pl. 2, Fig. 1). Matrix is formed by fine-grained biomicrite with echinoderm-fibrous microfacies. In upper part there are several millimetres thin layers, irregular laminas of black claystones that „flow round" (copy) the clast surface (Pl. 2, Fig. 1). The layer ends by black siliceous shales to silicites that form transition into dark-grey to black radiolarites overlying them.

Thickness: 12 m

Stratigraphic range: The age of the Olistostrome formation is estimated only indirectly by radiolaria from lithoclasts of radiolarites (see above) and by the position below dark radiolarites, which has been recently dated as „Late Bathonian and Early Callovian" (Ožvoldová 1998). Considering the fact that of radiolarians are from lithoclasts the age of the formation should be younger.

7) Ruhpoldin radiolarites occur as the known topmost member of the Jurassic succession at locality Bleskový Prameň. Their colour can be different, however the dark colour prevails, mainly dark-grey to black. There are also reddish, brownish or greenish shades (slopes of Drienkova Hora Mt.). The dark colour is considered to be original, while variegated colouring is the consequence of the weathering.

In radiolarites, except of radiolarians there are also clastic quartz and light – coloured mica, however, their contents do not exceed 1 %. Immediately overlying crinoidal limestones there are dark to black, banked radiolarites (10–15 cm, which are formed by thin beds 1-3-5 cm). Individual layers are separated by thin interlayers of black clayey shales. The fauna Late „Bathonian to Early Callovian" radiolarians is derived from these radiolarites (Ožvoldová, 1998). This age is identical with age of radiolarites lithoclast form underlying olistostrome formation, causing difficulties in age determination of the radiolarites. Considering the superposition, the Ruhpoldin radiolarites should be younger in age.

In radiolarites thin (maximum several dm) layers of carbonate sedimentary breccias to calcarenites occur, which were described by Mello (1973) for the first time. The breccias (fig. 5 a Pl. 1, Fig. 3) lie on positively graded sediments of distal turbidites. The turbidite

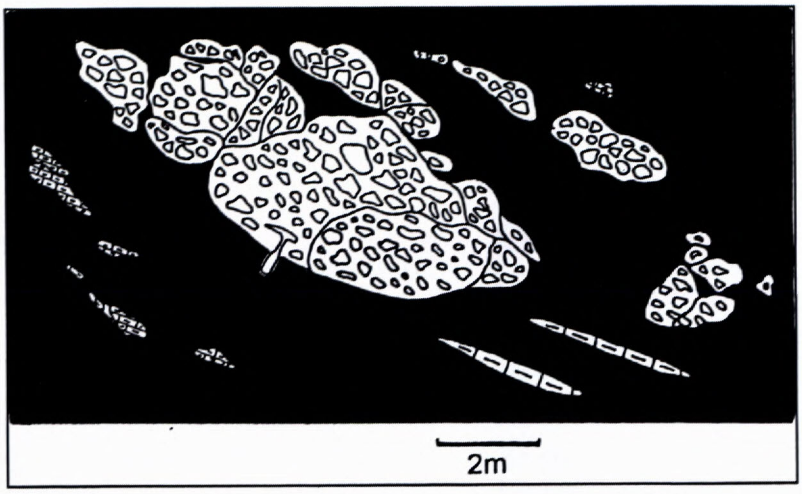

Fig. 6 Olistostromatic body in the Bohúňovo formation at the locality Bleskový prameň

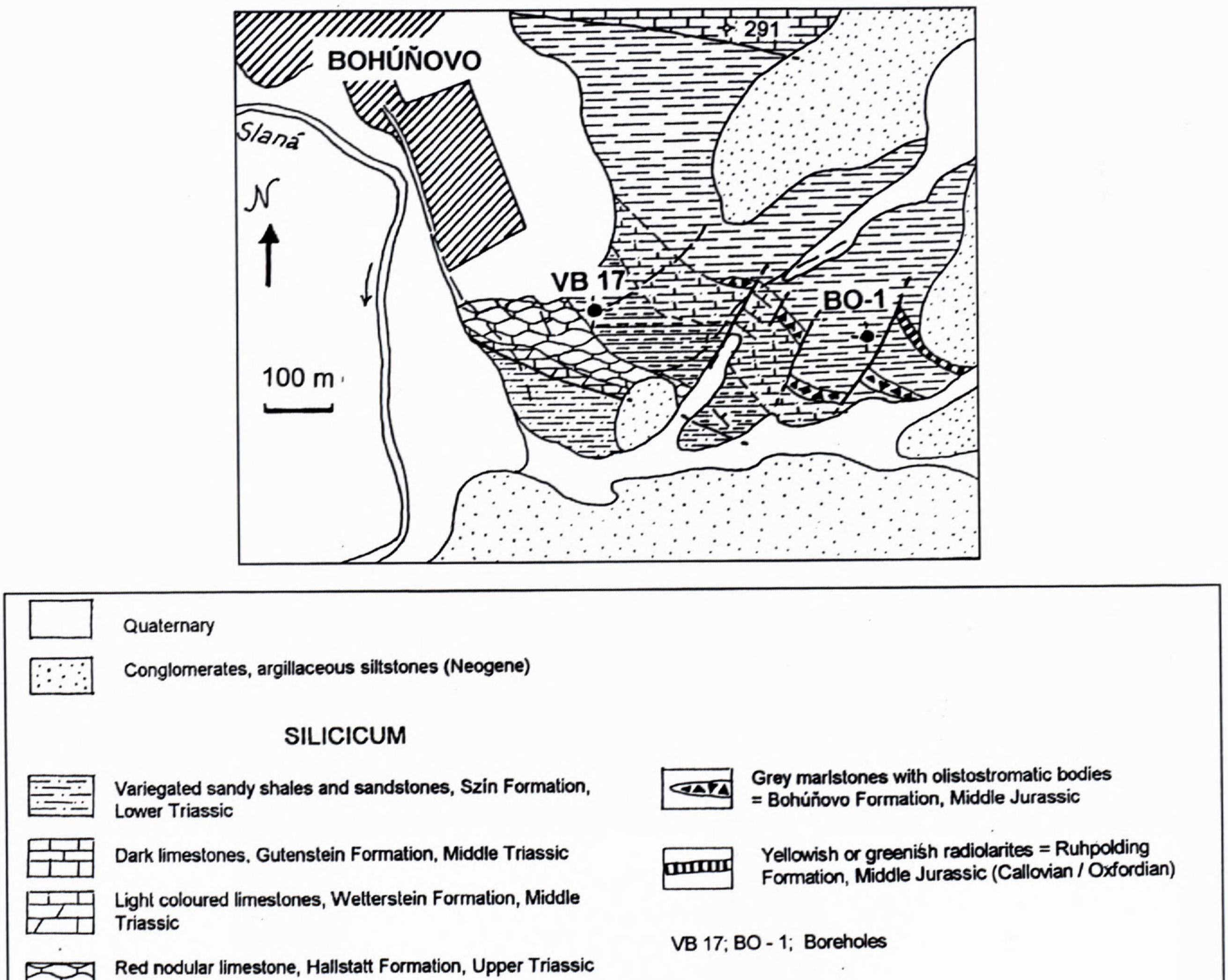

Fig. 7 Geological sketch map of the Bohúňovo vicinity (after Bystrický, 1962, completed by author)

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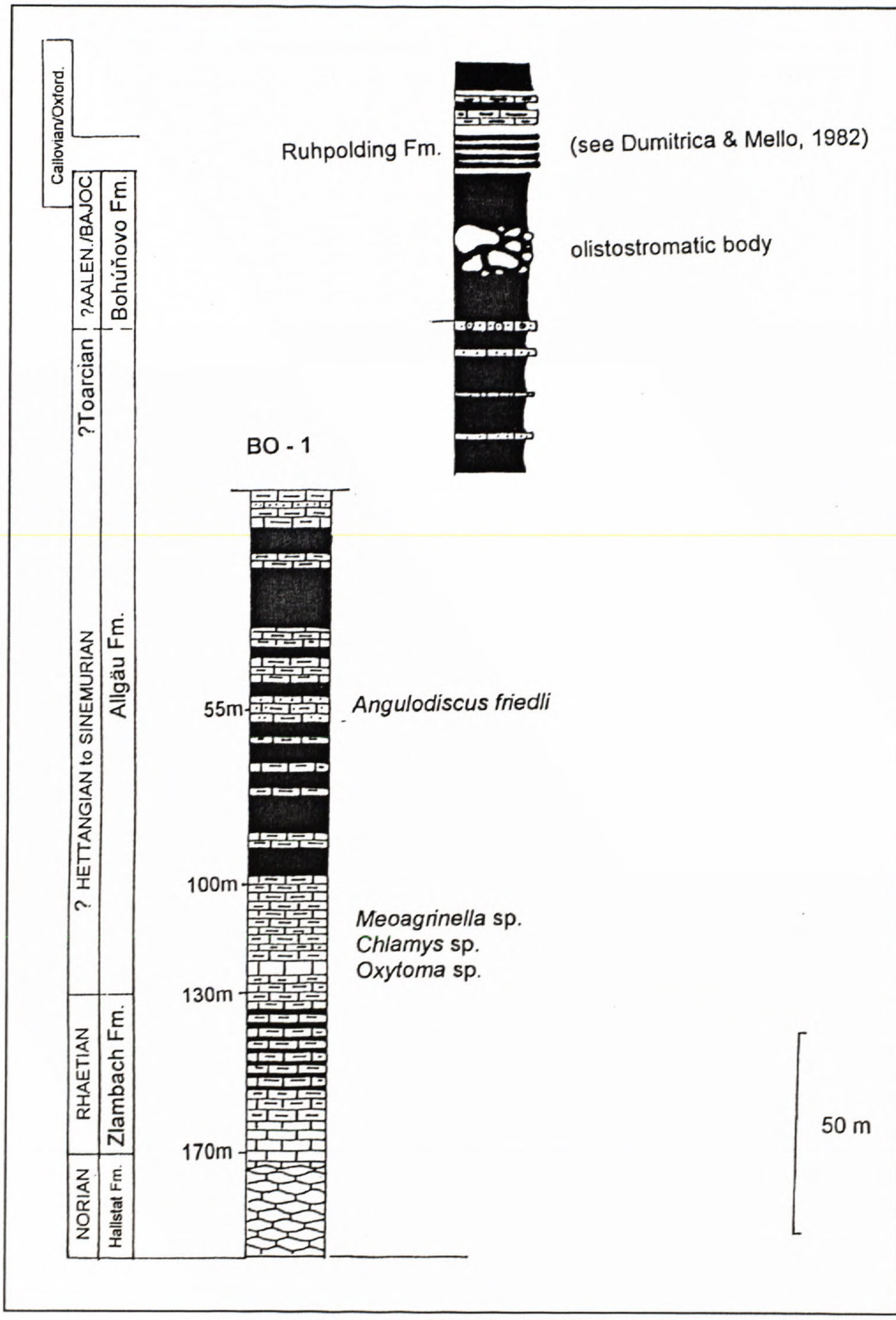

Fig. 8 Lithostratigraphic composite profile of Jurassic near Bohúňovo

and mica occur only seldom in sandstone. In radiolarites in which calcarenite is present, Bathonian–Early Callovian radiolarians were determined (Dumitrica - Mello, 1982). Because of bad exposure, the thickness is only estimated to 10–15 m.

The succession of this locality is ended by the formation of the radiolarites. Overlying it the early Triassic – Bodvaszilas and Szin members are present in tectonic position (Bystrický, 1964 a Mello, 1994).

Jurassic near by Lúčka village

The Jurassic sediments from these localities were described by Andrusov (1953) and Bystrický (1964). The Liassic part of the succession is less exposed in comparison with the previous locality. On the other hand, the Middle Jurassic – radiolarites are more abundant and form the majority of exposures. However, their present uncovering is quite poor in comparison with the later past, so the continuous profile cannot be studied here. However, parts of its sections.

On the south-western margin of Lúčka there is the exposure of the radiolarites in the road cut where Ondrejičková (1990) described the rich association of radiolarites: stratigraphic range of radiolarian association (based on two samples) is according to the authoress wide: uppermost Middle Jurassic (Callovian) to earlier part of Late Jurassic (Oxfordian).

Radiolarites are dark-grey, poorly spotted and weathering into brownish-yellow or rusty yellow colour. They are thin layered and platy and are characterised by clastic admixture (Pl. 6, Fig. 3) that is formed by quartz, muscovite, biotite and rarely zircon, rutile and tourmaline. The grains are of silt to fine-sand size. The content of terri-

laminas are thick 3–10 mm and formed by graded-bedded calcarenite (Pl. 4, Fig. 4), to everlying parts gradually passes into radiolarites. The grains in calarenite are bioclasts (fragments of echinoderms, uniserial foraminifers, tubes of worms, brachiopods, lamellibranchiates and zoospores). A cosiderable part of sediment is formed by micrite grains, in which the majority are formed by small fragments of micrites, some of them are Triassic (*Trochammina* sp. a *Semiinvoluta* sp.). Only seldom calcite ooides and lithoclasts of chloritised and calcitised volcanic rock (originally it contained thin phenocrysts of plagioklase) were found. Clastic quartz genous component is 1 – 2 %, seldom to 10 % (in bioturbated parts). There are rhombohedrons of disintegrated carbonates. New sampling for radiolarians was not successful and provided only poorly preserved associations of radiolarians that do not enable precise stratigraphic assignment.

Jurassic in the Miglinc valley (fig. 9)

This locality represents the most eastern occurrence of the Jurassic in the Silica nappe on Slovak territory. It was discovered by Bystricky (1960 and 1964) and in comparison with Bleskový Prameň, often the red nodular limestones and marls of "Ammonitico rosso" type – Adneth formation occur (fig. 9). In these limestones, there is rich association of Carixian to Early Domerian ammonites (Jamesoni/Ibex to Margaritatus Zones) Kollárová-Andrusovová, 1966). The lower part of the red nodular limestones consists of biomicrite (wackestone to packstone) and contains abundant fragments of lamellibranchiate shells, segments of echinodermates (mostly crinoids, sea urchins and ophiurians). There are often spicules of calcified silicispongies as well as foraminifers: *Lenticulina, Nodosaria, Ophtalmidium and Involutina.* Less frequent there are ostracods, gastropods, zoospores (*Globochaete alpina* LOMBARD) and bryozoans. Clastic quartz is observed very seldom, however, there are frequent findings of autigenic plagioklase of silt size.

In comparison with the previous limestones, the upper parts of the nodular limestones contain in the first place juvenile shells of lamellibranchiates (filaments) and ammonites (Pl. 6, Fig. 1). Foraminifers as *Ophtalmidium* and *Involutina* are missing in them. Calcified spicules of silicisponges are found rarely.

Overlying the red nodular limestones there is a formation of more or less grey to dark-grey clayey limeones that alternate with calcareous claystones (Fleckenmergel - Allgäu formation), from which Bystricky (1964) described the finding of the nautiloid *Cenoceras* cf. *intermedium* (SOW.). Unfortunately, stratigraphic value of this finding is not sufficient. Microfacially they are biomicrites – wackestones with relatively rich fragments of biodetritus (Pl. 6, Fig. 2), in which ostracods, echinoderm segments and less frequent uniserial foraminifers are present. The sediment is bioturbated and contains only low admixture of clastic quartz and micas of silt grain size. Some bigger bioclasts are „replaced„ by plagioclase (probably albite).

Jurassic in the Muráň river canyon (fig. 10)

The first reference to these occurrences can be found in works by Bystricky (1960, 1964) who has described small occurrences of crinoidal limestones that were classified as Jurassic, in the Muráň river valley, on both embankments, about 1 km southward of Meliata village on northern ending of the canyon. However, detailed information about these southernmost occurrences was missing.

Our research has shown that Jurassic limestones occur here as fillings of neptunian dikes, on northern end of the Muréň river canyon (on both sides) in the Late Triassic light - coloured limestones. Dikes are about 25 – 100 m long, the range of their width is from 5 to 8 m. Observable depth is at least 10 – 15 m. The strike dip is 110°, dipping 30° to 80°.

The lithological filling is variegated and variously grained types of limestones (from micrites to crinoidal sparites) red with transition to beige and grey colours occur there. The grey parts of the sediment consist of shells of juvenile ammonites, brachiopods and calcite cement. The voids in the mentioned bioclasts and original pores between the grains are often geopetally filled with the red wackestone (Pl. 6, Fig. 4). This consists of the micrite matrix, bioclasts from sporadical authigenic plagioclases and quartz. Bioclasts consist of fragments of juvenile ammonite shells, segments of crinoids (sporadically ophiura) and fragments of thin – walled lamellibranchiates (filaments). Gastropods and nodosaride foraminifers are there rare. The internal sediments are frequent, as well as RFC calcites (=„evinesponge structures"). The contact with the Late Triassic limestones is sharp and in the red Jurassic limestones angular fragments of light - coloured Triassic limestones can be found, what would point to activity of theses synsedimentary faults. In a small dike on the left-bank the fauna of ammonites in red biomicritic limestones was found:

Phylloceras sp., *Hildoceras* gr. *sublevisoni* FUC., *Hildoceras* cf. *lusitanicum* MEISTER, *Harpoceratinae* ex gr., *Dactylioceras* sp.

This association suggests the Middle Toarcian age, Bifrons Zone.

Because there are not any other rocks between the red Toarcien limestones and the light- coloured Late Triassic limestones, they represent the oldest known member of the Jurassic succession on this locality. This fact emphasizes the transgressive character of Jurassic in this part of Silicicum.

Jurassic near Bohúňovo (fig. 1, 7)

Unlike the previous locality the Jurassic near Bohúňovo is developed in more complete profile. This fact is probably caused by various positions in deposition area and it reflects the dynamics of the basin of the future Silicicum nappe.

The first published information about Jurassic near Bohúňovo is by Bystricky (1964: 78), who described it already in 1962 (manuscript). He classified as Jurassic the formation of dark clayey limestones, more or less spotted, endostratic breccias composed of red crinoidal limestones and radiolarites. The relation of the mentioned facial types was owing to their bad exposure very problematic. This lack was partly diminished by geological drilling BO-1 that was located (by Dr. Bystricky and one of authors M.R.) 600 m SE from Bohúňovo. The following profile was recorded in the drilling (Mello, 1973, appendix 9):

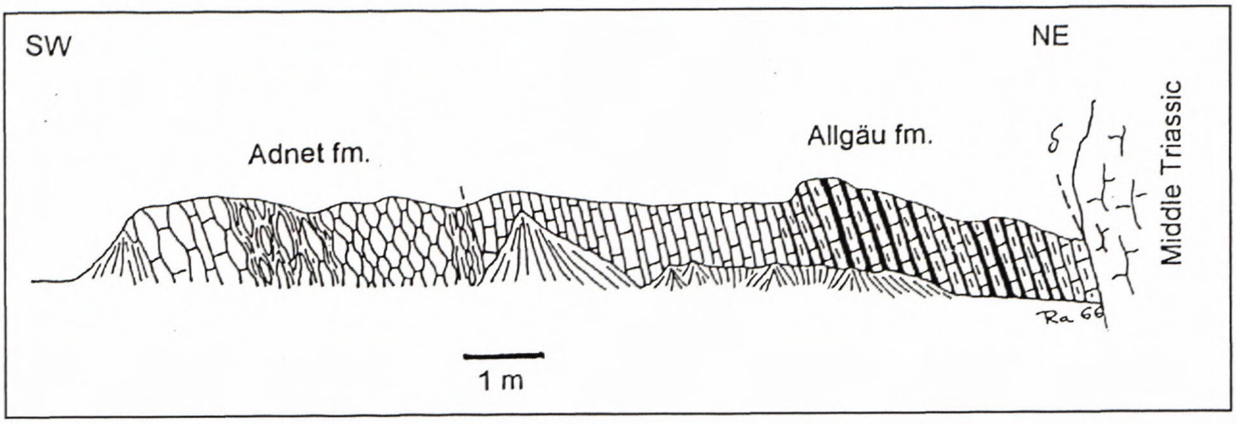

Fig. 9 Lithostratigraphic section through the Jurassic

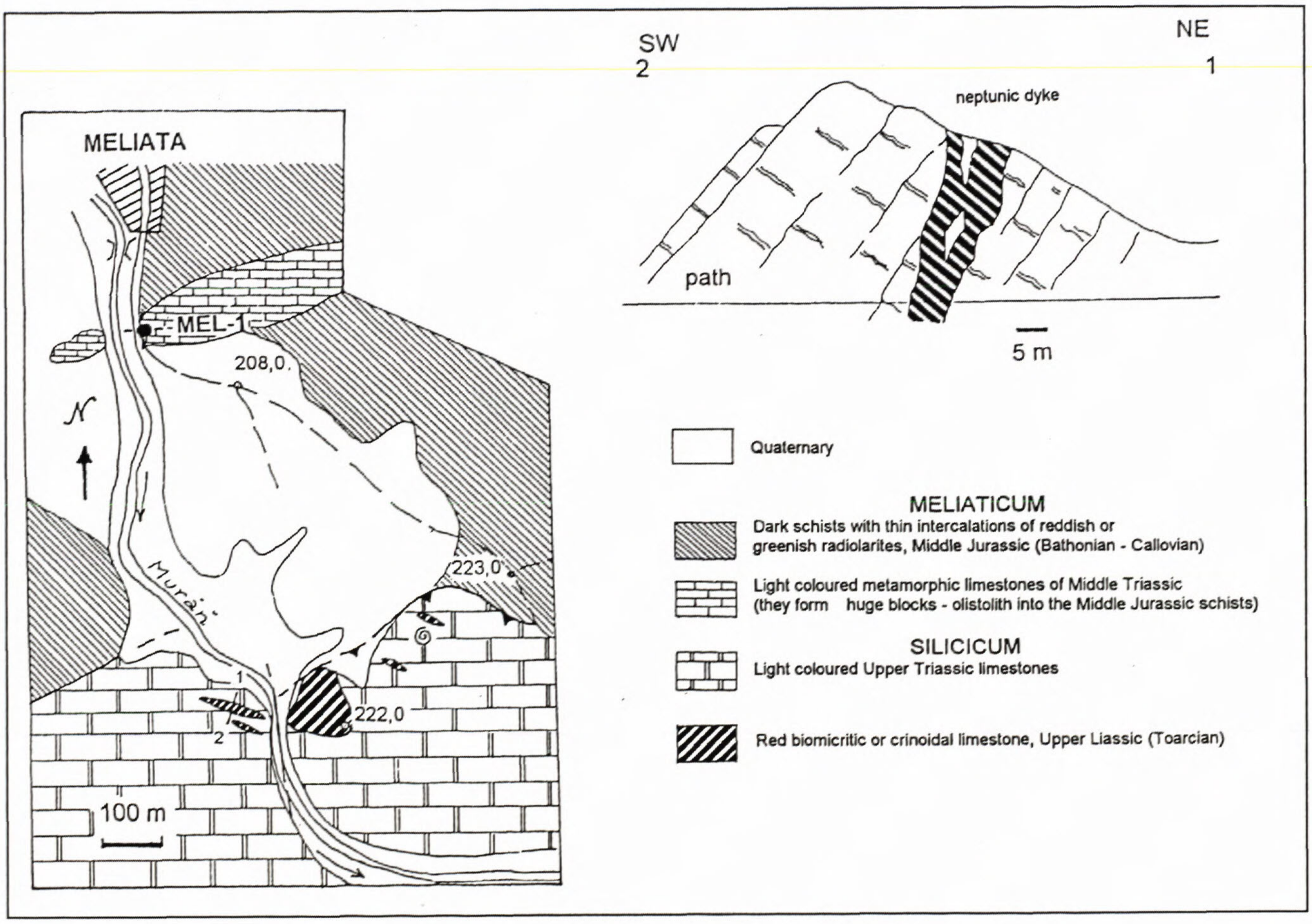

Fig. 10 Geological sketch map southern vicinity of Meliata village (after Mello, 1996, completed by author)

0–2 m — Quaternary,

2–12 m — dark-grey organodetritic, limestone layers (10, 20, 40 cm) with bed of calcareous sandstones (depth 9-10 m),

12–55 m — dark-grey calcareous claystones (prevailing) with layers of spotted clayey limestones - "Fleckenmergel" (=Allgäu formation)

55–61 m — dark-grey organodetritic limestones with sandy admixture and *Angulodiscus friedli* KRISTAN-TOLLMANN

61–100 m — dark-grey calcicareous claystones with layers of spotted clayey limestones ("Fleckenmergel"), in depth 88–92 m there is a layer of sandy–crinoidal limestones – calciturbidite

100–130 m — clayey spotted limestones with *Meoagrinella* sp., *Chlamys* sp. and *Oxytoma* sp. In interval 120 to 130 m passages of crinoidal-pellet at to oolitic biomicrites occur, which could correspond the turbidites. All layers mentioned above we includ into Early Liassic, but without detailed subdivision.

130–170 m — dark-grey clayey limestones and calcareous marls, locally spotted. The content of clayey limestones increases towards underlying parts. Facially these layers are well correlated with the

Zlambach formation at Malý Mlynský Vrch Mt., from which the fauna of ammonites of Norian-Rhaetian age is known.

170–200 m at the beginning there are pinkish, then red massive and nodular Hallstatt limestones (Norian).

The layer succession described above partly occurs on the surface in the gorge SE from the Bohúňovo village, from which similarly as in drilling, it is seen that in „Fleckenmergel" occur scattered beds (from 20 cm up to 1 m) of organodetritic weakly-sandy limestones. In upper part of the calcareous claystones formation (near the curve of the field path) there is a remarkable layer (about 5 m) of crinoidal limestones with intraclasts (up to 5 cm), which can have turbidite character.

Overlying these limestones the grey calcareous claystones occur again, in which Bystrický (1962) mapped endostratic breccias. The relation of these breccias to claystone formation was not known. Thanks to excavation works on gas transit pipeline (in neighbourhood of BO-1 drilling) the body of olistostrome formation was uncovered (= intraformational breccia of Bystricky) that is very similar to that one described in previous text on the Bleskový Prameň locality.

Bohúňovo formation: is an olistostrome composed of blocks of various sizes (several m^3 metres) and smaller clasts (20-30 cm^3 and less), of red crinoidal limestones, brecciated-crinoidal limestones and carcareous breccias (Pl. 1, Figs 1, 2, Pl. 7, Fig. 1). Further there are grey lumachelle limestones as well as limestones with Fe/Mn crusts. Blocks and lithoclasts laying in grey to yellowish-brown weathering clayey limestones to calcareous claystones.

The matrix of the breccia is calcareous-clayey with scattered minute lithoclasts spread in it (Pl. 7, Fig.2) and fragments of echinoderm segmants, foraminifers, ostracods, lamellibranchiates, brachiopods and seldom calcified radiolarians. Clastic quartz can be found rarely. The age of matrix is not reliably determined. In one sample Dr. POTFAJ determined the following nannoplankton association: *Ellipsagelosphaera fossacinata* BLACK, *Cyclagelosphaera deflandrei* (MANIVIT), *C. margerelii* NOEL, *? Biscutum* sp.. In case that this association is original, then its stratigraphic range is Middle Jurassic (? Bathonian) and younger.

The unsorted clasts in the breccia consist of grey, yellowish, pink and red limestones (Pl. 7, Figs 3, 4). Most ftequently there are biomicrites – wackestones and they have an association resembling biodetritus. They contain echinoderm segments, fragments of lamellibranchiates, foraminifers (*Involutina* sp., *Nodosaria* sp., *Lenticulina* sp. and *Ophtalmidium* sp.). The juvenile ammonites, gastropods, bryozoans, *Globochaete alpina* LOMB. and tubes of worms occur rarely. The crinoidal sparites of Liassic age were found rarely. Except of the limestones, the lithoclasts of claystones containing silty quartz are present. The ratio of matrix and lithoclasts (limestone-claystone) is very variable and changes in different parts of the exposure.

As mentioned above, the breccia near Bohúňovo resembles olistostrome sediments at the Bleskový Prameň locality. We did not find lithoclasts of demonstrably Triassic rocks as well as radiolarites that were mentioned by Bystricky. Moreover, the lithoclasts are not albitised.

The age of the Olistostrome formation has not been yet directly and reliably dated. However, if we consider the results of nannoplankton and position in the basement of the Callovian-Oxfordian radiolarites, then we can think about ? Bajocian – Bathonian age. The thickness of the formation is estimated to several tens metres.

Overlying of the olistostrome there are greenish-grey to yellowish-green weathering radiolarites (Ruhpolding radiolarites) with poorly observable thickness (poor exposure), in which rich association of radiolaria of Callovian-Oxfordian age was described (Dumitrica & Mello, 1982 and Ondrejičková, 1990). Younger members were not found because being covered by Neogene sediments.

Comments regarding the age of ruhpolding radiolarites of the Silicica nappe

Although the radiolarites of Silicicum do not reach remarkable thickness, they form a well distinguished and important regional correlation horizon. Moreover, in the Silicica nappe itself they can be the last known lithological member of the succession (Bleskový Prameň), preserved on the surface.

In the Bleskový Prameň locality above the radiolarites in tectonic position there is the Szin formation of Early Triassic of upper partial structure of the Silicicum nappe (Mello, 1993). Considering the age of closing and following structuration of sedimentary basin of Silicicum, this fact is very important. As we have stated above (1.c.), their stratigraphic assignment is understood variously. At the localities Lúčka and Bleskový Prameň they are stratigraphically ranged mainly to Late Bajocian-Bathonian up to Early Callovian (Goričan & Dogherty 1998 written announcement, Sýkora & Ožvoldová, 1995, Ožvoldová, 1998). In contrast to previous authors, only Ondrejičková (1990) considers their possible ranging to Callovian-Oxfordian. Regarding the radiolarites from Bohúňovo, these are dated as to Callovian-Oxfordian (Dumitrica & Mello, 1982 a Ondrejičková, 1990).

Although there are only three localities within Silicicum unit, considering their basinal and deep wather character, we suppose, that there should be one radiolarites horizon, stratigraphic range of which should be ? Late Bajocian to Oxfordian. However, the age determination of the radiolarites in Bleskový Prameň remains a problem. According to Ožvoldova (l.c.) the age of radiolaria clasts in the Bohúňovo formation and radiolarites overlying them is the same i.e. Bathonian-Early Callovian. As we have already stated, the age of radiolarites (in position above breccias) should be younger. From this viewpoint the age of radiolarites as mentioned by Dumitrica & Mello (1982) is more probable.

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Cephalopoda fauna and its stratigraphic evaluation

With respect to the fact that Liassic ammonites of Juhoslovenský Kras were in detail described in publication by Andrusovová-Kollárová (1966), in following we would be focused only on species that have not been described in this area up to now. The paleontologic material is deposited in collections of the **D. Štúrs´ State Geological Institute in Bratislava.**

NAUTILIDAE de BLAINVILLE, 1825
Cenoceras HYATT, 1883

***Cenoceras* aff. *jurense* (QUENSTEDT, 1846)**
Fig.11

Material: one incomplete stone cast, ex situ.
Remarks: our specimen is characterised by ventraly compressed cross´section of the whorl (fig. 11), what makes it most resemble to species *C. aratum* (QUENSTEDT, 1846). However it differs from that species by shallow internal lobe (fig.11).
Stratigraphic range and occurrence: the species occurs mainly in Early Liassic, but it can be found in Upper Liassic as well. Our specimen was found together with the Middle Liassic ammonites on the locality northward from Muráňska Huta (Muranska Planina plateau) at margin of meadow near the elevation point 808,2 m.

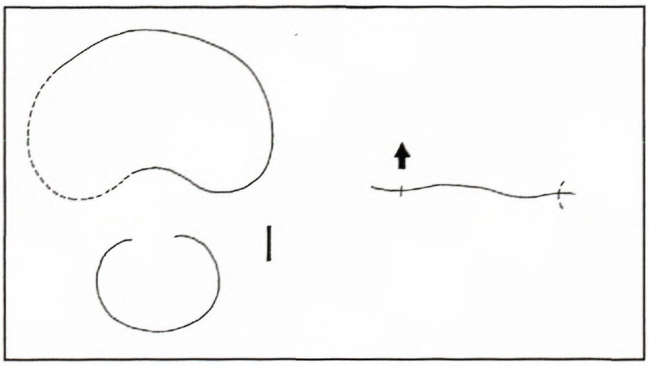

Fig. 11

JURAPHYLLITIDAE ARKELL, 1950
***Juraphyllites* MÜLLER, 1939**

***Juraphyllites* cf. *planispira* (REYNES, 1868)**

Material: three incomplete stone casts drill cores of red weakly-crinoidal limestone
Remarks: Specimens from Bleskový Prameň locality are similar to species *J. planispira* (REYNČS) considering their laterally compressed crossection of whorl, smooth and flat sides and stratigraphic position.
Stratigraphic range and occurrence: Carixian – Early Domerian, locality Bleskový Prameň, layer No.3 (see profile, text. -fig. 5).

PHYLLOCERATIDAE ZITTEL, 1884
***Phylloceras* SUESS, 1865**
***Phylloceras* sp.**

Material: one incomplete stone cast
Remarks: our specimen represents a juvenile specimen that cannot be reliably determined. It occurs together with *Hildoceras.*
Stratigraphic range and occurrence: Toarcian, zone Bifrons, left bank of the Muráň river, southward of Meliata, NE from the elevation point 220,0 m.

CALLIPHYLLOCERATINAE SPATH, 1926
Calliphylloceras SPATH, 1927
***Calliphylloceras* sp.**

Material: one incomplete stone core, ex situ

Dimensions: D	Wh	Ww	O
78,0	42,0	-	10,5

Notes: because of its poor preservation nearer its determination was not possible. According to the total proportions and relatively wide umbilicles our specimen is similar to species *C. liasicum* GÉCZY, 1967.
Stratigraphic range and occurrence: Middle Liassic – Pliensbachian, northward from Muránska Huta (Muránska Planina plateau), at margin of the meadow near the elev. point 808,2 m.

LYTOCERATIDAE NEUMAYR, 1875
Lytoceras SUESS, 1865

***Lytoceras* cf. *postfimbriatum* PRINZ, 1904**

Material: two incomplete, partly preserved stone cores, ex situ

Parameters:	D	Wh	Ww	O
	105,0	37,0	26,0	57,0

Note: in the level degree of coiling and laterally compressed – elliptical cross of whorl our specimens are similar to species L. postfimbriatum PRINZ, 1904.
Stratigraphic range and occurrence: the species is known from Middle Liassic – Pliensbachian of the Western Carpathians (localities Borišov and Rovne pod Krížnou), where it occurs together with *Uptonia.* Our specimens were found northward of Muránska Huta (Muránska Planina plateau), at margin of the meadow near the elev. point 808,2 m.

***Lytoceras* cf. *fimbriatum* (SOWERBY, 1817)**

Material: one incomplete imprint, ex situ
Notes: our specimen represents incomplete imprint of whorl in greyish-green weakly-crinoidal limestone with distinct traces of collars with typical crenulate margin. Although there is only an imprint, on the basis of collars we could range our specimen to *L. gr. fimbriatum* (Sow.).
Stratigraphic range and occurrence: the species was found in Geravy near the monument and it is ranged to Middle Liassic – Pliensbachian.

OXYNOTICERATIDAE HYATT, 1875
Oxynoticeras HYATT, 1875

***Oxynoticeras* cf. *oxynotum* (QUENSTEDT, 1845)**
Pl. 10, Fig. 4

Material: one partly preserved stone core, ex situ

Dimensions:	D	Wh	Ww	O
	62,0	32,4	-	6,5

Notes: Regarding the cross section of the whorl, sharp keel and degreelevel of involution our specimen resembles *Ox. oxynotum* (QU.), which is common species of Carpathians´ Lotharingian,.
Stratigraphic range and occurrence: Early Liassic – Lotharingian. Zone Oxynotum, northward of Muránska Huta (Muránska Planina plateau) at the margin of the meadow near the elev. point 808,2 m.

EODEROCERATIDAE SPATH, 1929
***Epideroceras* SPATH, 1923**

***Epideroceras* sp. 1**

Material: one partly preserved stone core, ex situ
Notes: In the degree of the involution, radial and relatively wide flat ribs and highly oval cross section of whorl our specimen is close to species *Epideroceras roberti* (HAUER, 1854) or *E. steinmanni* (HUG,1899).
Stratigraphic range and occurrence: The species mentioned above occur in Lotharingian in the Raricostatum zone, northward of Muránska Huta (Muránska Planina plateau). Margin of the meadow near the elev. point 808,2 m.

***Epideroceras* cf. *lorioli* (HUG, 1899)**
Fig. 12

Material: one partly corroded rock stone core, ex situ

Dimensions:	D	Wh	Ww	O
	225,0	68,6	47,0	105,6

Notes: This big form is characterized by laterally compressed, oval cross section of whorl (fig.12). Its immature stage is characterized by radiate rounded ribs with obscure tubercles. Overall appearance, but mainly the degree of volution and ribbing of our specimen resemble *Epideroceras lorioli* (Hug).

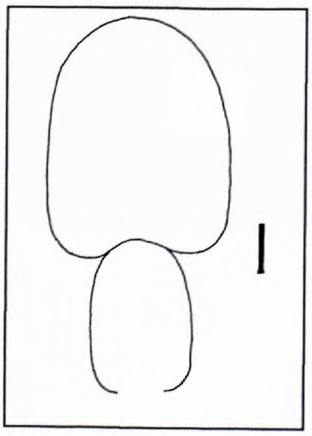

Fig. 12

Stratigraphic range and occurrence: this species occurs in Lotharingian, Raricostatun zone, northward of Muránska Huta (Muránska planina plateau), the margin of the meadow near the elev. point 808,2 m.

POLYMORPHITIDAE SPATH, 1929
***Uptonia* BUCKMAN, 1898**

***Uptonia* sp.**
Fig. 13

Material: part of the whorl of the middle sized specimen, ex situ
Notes: our specimen has laterally compressed whorl section of whorl (fig.13) with remarkable prorsiradiate ribs, which cross up the ventrum forming „chevrons". The ribbing type range our specimen to genus Uptonia, but the species could not be determined due to more precisely poor preservation.

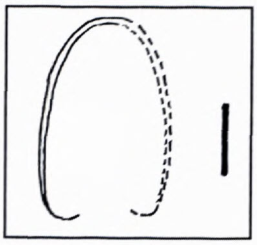

Fig. 13

Stratigraphic range and occurrence: Early Carixian, zone with Uptonia jamesoni, Geravy (Stratenská Dolina valley), northward of cableway, near the monument.

ACANTHOPLEUROCERATINAE Arkell, 1950
Tropidoceras Hyatt, 1867

***Tropidoceras* ? sp.**

Material: one incomplete stone core, ex situ
Notes: Although the specimen is poorly preserved, the whorl section of whorl as well as degree of volution indicates the genus *Tropidoceras.*
Stratigraphic range and occurrence: Carixian, Ibex Zone, northward of Muránska Huta, the margin of the meadow near the elev. point 808,2 m.

LIPAROCERATIDAE HYATT, 1867
***Androgynoceras* HYATT, 1867**
***Androgynoceras* cf. *maculatum* (YOUNG & BIRD, 1822)**

Material: one incomplete stone core, ex situ
Notes: despite of partial preservation of our specimen, by its robust and strong ribs distant from each other mostly resembles *A. maculatum* (Y. & B.).
Stratigraphic range and occurrence: Carixian, Davoei Zone, northward of Muránska Huta (Muránska Planina plateau), the margin of the meadow near elev. point 808,2 m.

***Androgynoceras* sp. juv.**

Material: four incomplete stone cores
Notes: on locality Bleskový Prameň there occur several not adult specimens belonging to genus Androgynoceras. These pieces resemble mostly species *A. capricornum* (SCHLOTH.) the general rib type. However, due to preservation as well as the size of the specimens (max. diameter is 25 cm) their closser determination is practically impossible.
Stratigraphic range and occurrence: Carixian, Ibex/Davoei Zone, locality Bleskový Prameň, layers no.3 (see profile).

DACTYLIOCERATIDAE HYATT, 1867

***Dactylioceras* HYATT, 1867**

***Dactylioceras* sp.**

Material: two fragments of whorls

Notes: On locality Bleskový Prameň and southward of Meliata two fragments of whorl parts were found, which undoubtedly belong to this genus. Due to the poor preservation, their specific determination was not possible.

Stratigraphic range and occurrence: Middle Toarcian, Bifrons Zone, locality: Bleskový Prameň, layer 4 (together with H. sublevisoni) and southward of Meliata, NE of elev. point 220,0 m, left bank of the Muráň river.

HILDOCERATIDAE HYATT, 1867

HARPOCERATINAE NEUMAYR, 1875

***Protogrammoceras* SPATH, 1913**

***Protogrammoceras* gr. *isslei* (FUCINI, 1900)**

Pl. 10, Fig. 2

Material: one incomplete stone core, ex situ

Notes: the specimen from Muránska Planina plateau mostly resembles *"P." isslei* (FUC.) by its densely spaced sigmoidal ribs, which are more distinct towards the ventrum. Other mark that makes the specimen resembling to this species is that ribs practically have not ventral projection and end on the strip accompanying the keel.

Stratigraphic range and occurrence: ? Late Carixian – Early Domerian (Stokesi Zone), northward of Muránska Huta (Muránska Planina plateau), the margin of the meadow, near the elev. point 808,2 m.

***Protogrammoceras* cf. *normanianum* (d´ORBIGNY, 1844)**

Pl. 10, Fig. 1

Material: one partly deformed stone core, ex situ

Notes: the subadult stages are characterized by laterally compressed whorl section.The ornamentation is represented by dense, distinct strong, rursiradiate and bifurcate ribs. The branching occurs near umbilicum, in the place of branching there are indications of slight swelling sometimes. The last preserved whorl keeps the same style of branching, but the ribs are remarkably less distinct, without ventral projection.

Due to the overall volution as well as character of ribs our specimen approximates to the species *P. normanianum* (d´ORB.). It is necessary to say that in the Early Domerian of Tethys realm a plenty of species have been described, but their reliable distinction is often very problematic (cf. Dommergues et al., 1987)

Stratigraphic range and occurrence: ? Late Carixian – Early Domerian, Stockesi Zone, northward of Muránska Huta (Muránska Planina plateau), the margin of the meadow near the elev. point 808,2 m.

***Hildoceras* HYATT, 1867**

***Hildoceras sublevisoni* FUCINI, 1919**

Fig. 14, Pl. 9, Figs. 1, 2

1919 *Hildoceras sublevisoni* nov. sp.- FUCINI: 182 pars

1976 *Hildoceras sublevisoni* FUCINI, 1919 - GYBILLY: 128-135, Pl. 20, Figs. 6-7, Pl. 21, Fig. 5, Pl. 22, Figs. 1,2 (cum syn.)

Material: eight incomplete specimens (parts of whorls in various growth stages)

Remarks: our specimens are owing to their cross section of whorl and type of ribbing of the subadult whorls well correlated with descriptions and figures of species described by Gabilly (1976) in his monograph.

Stratigraphic range and occurrence: Middle Toarcian, Bifrons Zone, locality Bleskový Prameň, layer 4 (sample BP/6).

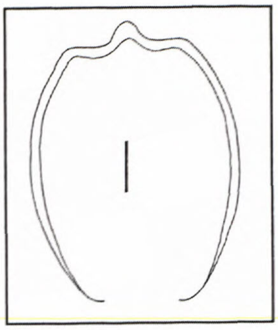

Fig. 14

***Hildoceras* gr. *sublevisoni* FUCINI, 1919**

Pl. 9, Fig. 4

Material: eight more or less complete stone cores

Notes: several subadult stages (total average is about 30 mm) come from the locality southward of Meliata, which resemble species *H. laticosta* Bellini, 1900 by their type of rib distribution. However, GABILLY (1976: 132) considered this species as synonym of species *H. sublevisoni.* Due to the quality of preservation as well as due to the subadult stage of our specimens it is not possible to determine their precise attribution.

Stratigraphic range and occurrence: Middle Toarcian, Bifrons Zone, southward of Meliata, left bank of the Muráň river, NE from the elev. point 220,0 m.

***Hildoceras* cf. *lusitanicum* MEISTER, 1913**

Pl. 9, Fig. 3

Material: two stone cores

Notes: Considering the type and density of ribbing our specimens, although in subadult stage, mostly resemble species *H. lusitanicum* MEIST.

Stratigraphic range and occurrence: Middle Toarcian, Bifrons Zone, left bank of the Muráň river, NE from the elev. point 220,0 m.

Paleogeographic and geodynamic development of Jurassic in Silicicum

Although the reconstruction of the Jurassic history of Silicicum is risky, we suppose that it is an inevitable step for understanding of its own geodynamic development as well as neighbouring palaeographic regions. First of all the main risk is in the incomplete and poorly preserved Jurassic succession, which does not enable to create a relatively realistic picture of the distribution of facies in this area. On the other hand, Jurassic sediments form the last preserved sedimentary record of Silicicum, which is connected (at least in its basin parts) to Triassic cycle and it provides good information about the conditions in this area before its closing. This moment seems to be very important in reconstruction of the geodynamic development of the Silicicum.

It is obvious from the general paleogeographic picture of the inner most units of the Western Carpathians, that the leading element in this region during Jurassic period, there was the oceanic domain of Meliaticum. Its geodynamic development and its consequent Late Jurassic closing had a direct influence on the development and character of the Jurassic sediments in Silicicum (Rakús, 1996).

During Late Triassic and Early Jurassic era the paleogeographic domain of Silicicum was divided by system of normal synsedimentary faults into elevations (horst) and basin areas. This basic paleogeographic element controlled the distribution and character of the Liassic facies of Silicicum. In elevated zones (for instance, Muránska Plošina plateau, Goštanová near Tisovec, Geravy - Stratenská hornatina Mts.), Drienková hora Mt., the Muráň river canyon southward of Meliata village), the Liassic limestones lie with bigger or smaller hiatus on the Norian Dachstein limestones and they are in transgressive position. The transgressive development of Liassic is underlined not only by the brecciated development of basal members with a plenty of late Triassic limestones clasts (Bleskový Prameň), but also by the fact that nowhere the sediments of Rhaetian, Hettangian and lowest Sinemurian were found! The continuing rifting accompanyed with extension caused also the development of new opened faults in subjacent Late Triassic limestones that were consequently filled with the Liasssic limestones. The depth reach of these faults can be very deep and can reach more than 100 m (the wall of Geravy near gamekeeper´s Biele Vody or drilling close to Bleskoý Prameň). The filling of the neptunian dikes consists mostly of variegated red biomicrite, probably Middle Liassic, or of red Toarcian biomicrites (the Muráň river canyon, southward of Meliata village). On the last mentioned locality there is very distinct transgressive character of Liassic in horst zones. The presence of neptunian dikes in elevated areas of Silicicum seems to be characteristic for this region unlike, for instance in Hronicum.

In basin parts of Silicicum (Bohúňovo, Tiba) Liassic sediments develop continuously from the Zlambach formation (Late Norian/Rhaetian) and they are represented by development of spotted calcareous claystones and clayey limestones "Fleckenmergel" (Allgäu formation) with beds of sandy-crinoidal limestones to calcareous sandstones of calciturbidite character. In Geravy the formation of dark shales and biomicritic limestones with spongolites can correspond to Late Liassic. A rare phenomenon in this area is the presence of basaltic volcanism, which occurs locally only (locality Geravy).

In Muránska planina localities the slope-basinal character of sediments can be defined since Lotharingian and it is probable that it lasted during Late Liassic as well. From total facial regime of Liassic in Silicicum we can state the distinctive trend of deepening – „pelagisation“ of its area, which reached its maximum later, by the end of Middle Jurassic only.

At the beginning of Dogger (?Aalenian/Bajocian) the debris flow type olistostromes occurred (Bohúňovo formation), which had enigmatic origin. Although the material composition indicates its intra-Silicicum origin, but the location of the elevations (escarpment) in the basin itself is unknown. We could assume that the olistostromes reflect the tectonic activity in the Silicicum area itself due to starting subduction of the Meliaticum domain.

The Silicicum area reached the maximum deepening at the end of Bathonian/Callovian up to Oxfordian, when the deep wather, typically basinal deposition of non-calcareous radiolarites existed here. Despite of deep wather basinal conditions, the calciturbidites with thin layers of synsedimentary breccias (Bleskový Prameň) occurred, which clearly demonstrate dissection of the basin.

The Late Jurassic (Kimmeridgian), in case that it is preserved in situ (data of Kullmanová, 1963 from Geravy) or from the secondary occurrence (Mišík & Sýkora, 1980) is characterized by shallower although pelagic development. The latest Jurassic – Tithonian does not occur anywhere in situ in our territory. However it is known from secondary occurrences in facies of algal-Clypeina limestones (Mišík & Sýkora, 1980).

In Kimmeridgian era (about 153 Ma) there was closing followed by subduction of the Meliaticum oceanic domain (Malouski et al., 1993, Dalmayer et al., 1996, Rakús, 1996 and Faryad, 1997). This event was manifested in the Silicicum area by closing of the space, what caused the formation of the nappe structure with outward vergency (northward in the present-day co-ordinates). This situation is indicated also by tectonic superposition of Early Triassic on the radiolarites of Middle Jurassic, as it can be seen at locality Bleskový Prameň (Mello, 1996).

Facies of uppermost Jurassic – Tithonian, even they are known only from secondary occurrences in our area, were deposited in extremely shallow water environment. This points to great facial contrast between Dogger – Early Malm and Tithonian! This phenomenon cannot be explained by gradual shallowing of the Silicicum area. It seems that the only logic explanation of this facial contrast is development of the nappe structure from the rock complexes of the „Pre-Tithonian“ Silicicum. The shallow-water Tithonian algal limestones should rest on this structure as the new and last Jurassic cycle that closes the sedimentary record in Silicicum area. With regard to the chronic missing of Early Cretaceous sediments in Silicicum we could think about it as the area without deposition in contrary to Hronicum, for instance, where the deposition lasted to Late Hauterivian. The new deposition cycle begins in Late Cretaceous – Senonian with lagoonal-marine sediments only.

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Explanations to photo-plates

Plate 1.

1, 2 Carbonate sedimentary breccia (debris flow) of Dogger. Clasts are formed by various varieties of crinoidal biomicrites, reddish-violet, red and grey colours. Clasts are poorly rounded, the matrix consists of grey to beige, more or less consolidated marlstone. Locality Bohúňovo. Gas transit pipeline.

3 Black radiolarite (lower part) with graded laminae and thin bed of carbonate sedimentary breccia (upper part). Locality Bleskový Prameň, ex situ, lgt. M. Havrila.

Plate 2

1 Grey-green crinoidal biomicrites with lithoclasts (intraclasts) of lighter - coloured varieties, which are replaced by darker layer with rounded lithoclasts of grey crinoidal biomicrites that „flow round" the dark claystones with light coloured laminae of biomicrites towards overlying parts. On this part the thin bed of black siliceous consolidated claystones (? silcretes) rests. Overlying them occurs the first bed of black radiolarite. Locality Bleskový Prameň, ?Bajocian, sample BP/10.

2,3 Types of the Dogger breccias (debris flow) with lithoclasts of light-grey biomicrite , fragments of megalodonts (me) and lithoclast of greyish-green radiolarite (ra). Matrix consists of grey calcareous claystone with transitions into clayey limestone. Locality Bleskový Prameň, ? Bajocian, sample 9a.

Plate 3

1 Red "Hierlatz-Adneth" limestones with irregular disseminated segments of crinoids (co = columnaria, ba = basalia), rostra of belemnites (= b ? Passaloteuthis sp.), ammonites (genera Phylloceras, Juraphyllites and ?Tropidoceras) and intraclasts with dark hematite coat. Locality Bleskový Prameň, Carixian, the sample position between BP/5 a BP/6, lgt. J. Mello.

2 Synsedimentary fold (size about 5 cm) in Dogger olistostrome. Locality Bleskový Prameň, ex situ, probably near the sample BP/9.

3 Lithoclasts of the greyish-green to dark-grey radiolarite in Dogger breccia (debris flow). Locality Bleskový Prameň, ex situ, sample BP/12 - 13.

Plate 4

1 Grey grainstone with bioclasts and intraclasts, lithoclast of Dachstein limestone (Late Triassic – Norian)) in basal parts of Liassic, locality Bleskový Prameň, sample BP/3, magnified 10 times.

2 Wackestone- red fine-grained limestone of Adneth type with fragmentary biodetritus of thin-walled lamellibranchiates, ammonites and spicules of silicisponges, Late Liassic – Middle Toarcian, Bifrons Zone, locality Bleskový Prameň, sample BP/6 (thin section 22 640), magnified 10 times.

3 Lithoclast of the grey limestone of Dogger olistostrome, wackestone / packstone with fine biodetritus of juvenile ammonites shells, foraminifers, segments of echinoderms, spicules of silicisponges and ostracods, Dogger, locality Bleskový Prameň, sample BP/9 (thin section 22 822), magnified 26 times.

4 Laminae of the graded bedded clastic limestone in radiolarite, Late Bathonian – Early Callovian, locality Bleskový Prameň, ex situ, (thin section 22 637), magnified 10 times.

Plate 5

1 Coarse-clastic limestone with lithoclasts of limestones and bioclasts mainly of crinoidal segments in the micrite matrix, Lias, locality Bleskový Prameň, (thin section 9405), magnified 7,7 times.

2 Lithoclast of Liassic limestone in the Dogger carbonate breccia – olistostrome, wackestone with spicules of silicisponges, fragments of lamellibranchiate shells and segments of echinodermats, locality Bleskový Prameň, sample BP/9, magnified 26 times.

3 Lithoclast of the radiolarite in the Dogger olistostrome, Dogger, locality Bleskový Prameň, ex situ, length of the line is 2 cm.

4 Unsorted clastic limestone with lithoclasts and bioclasts of various size in top part of the Dogger olistostrome, Dogger, locality Bleskový Prameň, sample BP/10, (thin section 22 679), magnified 7,7 times.

Plate 6

1 Adnet limestone, packstone with many fragments of lamellibranchiate shells, segments of echinodermates and juvenile ammonites, Late Liassic – Toarcian, locality Miglinc valley, (thin section 9414), magnified 26 times.

2 Wackestone with fragmentary detritus composed of ostracods and lamellibranchiate shells, segments of echinodermates, Late Liassic, locality Miglinc valley, (thin section 24 153), magnified 44 times.

3 Lenticle of siltstone (clastic quartz and mica) in the radiolarite, Dogger, locality Lúčka (thin section 23 476), magnified 44 times.

4 Bioclastic rudstone (filling of dike in the Dachstein limestone) contains shells of ammonites and segments of crinoids, in voids there are often geopetal structures (the picture is negative!), Middle Toarcian, (thin section 25259), magnified 5 times.

Plate 7

1 Bioclastic limestone – breccia with large limestones lithoclats, Dogger, locality Bohúňovo, gas transit pipeline, (thin section 22 737), magnified 7 times.

2 Claystone lithoclasts , limestones and bioclasts as part of olistostrome sediments, matrix is clayey-calcareous, Dogger, locality Bohúňovo, gas transit pipeline, (thin section 22 639), magnified 26 times.

3 Wackestone/packstone lithoclast with Liassic microfossils , also *Involutina liassica* in the Dogger olistostrome, locality Bohúňovo, gas transit pipeline, (thin section 22 732), magnified 26 times.

4 Liassic limestones lithoclast in the Dogger olistostrome, packstone with echinoderm segments, foraminifers, brachiopods and worm tubes, locality Bohúňovo, (thin section 22 729), magnified 26 times.

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Plate 8

1 Rudstone with rounded limestone lithoclasts, shells of thick-walled lamellibranchiates hydrozoans, segments of echinoderms, Liassic, locality northward of Pila near Hrabušice village, (thin section 22 644), magnified 7x times.
2 The Same thin section, magnified 26 times.
3 Wackestone with cross of gastropods, juvenile ammonite and crinoid segments, Middle Liassic – Carixian, locality northward of Muránska Huta near the elev. point 808,2m (thin section 22 638), magnified 26 times.
4 Packstone with foraminifers *Globuligerina* sp. *Lenticulina* sp. *Tetrataxis* sp, fragments of thin walled lamellibranchiate shells and segments of echinoderms, Middle Jurassic – Callovian, locality Geravy, sample G-1, magnified 26 times.

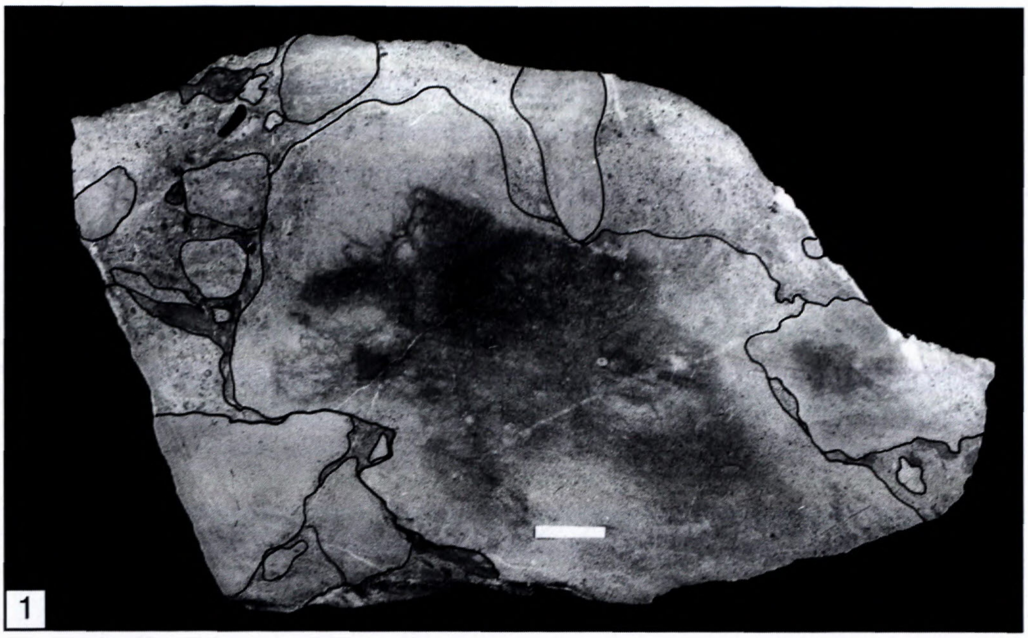
Plate 9

1 *Hildoceras sublevisoni* FUCINI, 1919, Middle Toarcian, Bifrons Zone, locality Bleskový Prameň, sample BP/6, slightly magnified.
2 *Hildoceras sublevisoni* FUCINI, 1919, part of the whorl of the immature specimen, Middle Toarcian, Bifrons Zone, locality Bleskový Prameň, sample BP/6, magnified 2 times.
3 *Hildoceras cf. lusitanicum* MEISTER, 1913, Middle Toarcian, Bifrons Zone , locality: the left-bank side of the Muráň river canyon, near the elev. point 222,0m, southward of Meliata village, magnified one time.
4 *Hildoceras* gr. *sublevisoni* FUCINI, 1919, Middle Toarcian, Bifrons Zone , locality: the left-bank side of the Muráň river canyon , near the elev. point 222,0m, southward of Meliata village, magnified one time.
5 ? *Pseudogrammoceras* sp., Middle Toarcian, Bifrons Zone, locality: the left-bank side of the Muráň river canyon , near the elev. point 222,0m, southward of Meliata village, magnified 0,5 times.
6 bottom part of calyx of crinoid with basalias, Middle Liassic, locality Bleskový Prameň, ex situ, natural size.

Plate 10

1 *Protogrammoceras* cf. *normanianum* (d'ORBIGNY, 1844), Middle Liassic, ? Late Carixian – Early Domerian, ex situ, locality northward of Muránska Huta, near the elev. point 808,2m, magnified 0,5 times.
2 *Protogrammoceras* gr. *isslei* FUCINI, 1900, Middle Liassic, ? Late Carixian – Early Domerian, ex situ, locality northern of Muránska Huta, near the elev. point 808,2m, magnified one time.
3 Bottom part of the crinoidal calyx with basalia and columnalia, Middle Liassic, locality Bleskový Prameň, ex situ, slightly magnified.
4 *Oxynoticeras* cf. *oxynotum* (QUENSTEDT, 1845), Lotharingian, Oxynotum Zone, locality northward of Muránska Huta, near the elev. point 808,2m, ex situ, slightly magnified.
5 *Androgynoceras* sp. juv., Middle Liassic, Carixian, locality Bleskový Prameň (text. - fig. 5), magnified 2,2 times.
6 *Hildoceras* cf. *sublevisoni* Fucini, 1919, Middle Toarcian, Bifrons Zone, locality Bleskový Prameň, sample BP/6, natural size.

The paper was worked out within the project „Geodynamic Development of the Western Carpathians" and the authors devote it in to the honour of RNDr.JÁN BYSTRICKÝ DrSC., excellent geologist and specialist of Mesozoic of the Western Carpathians.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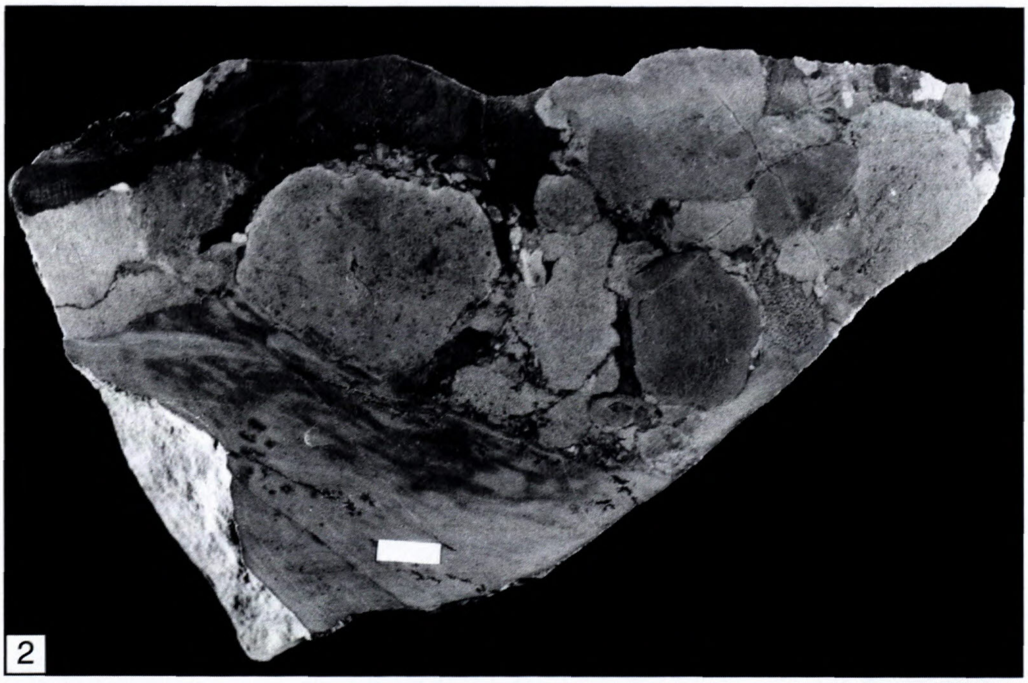
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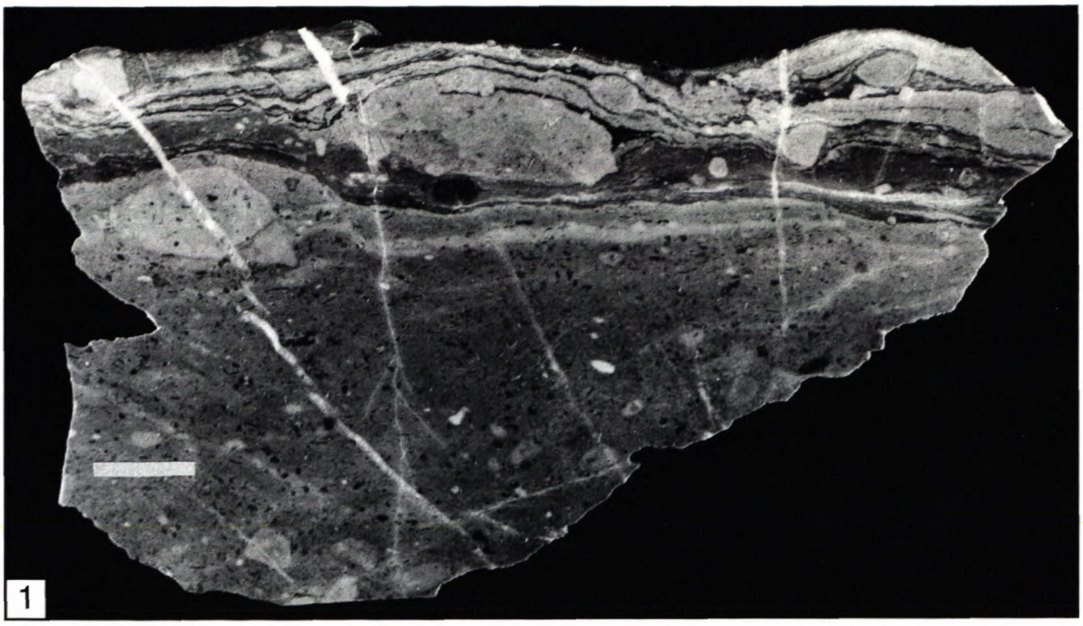

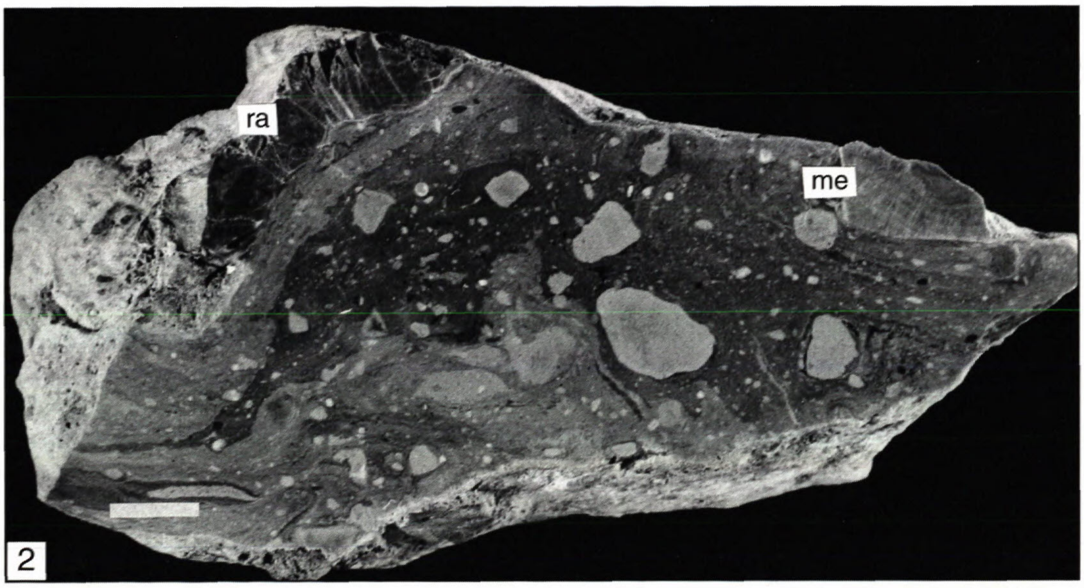

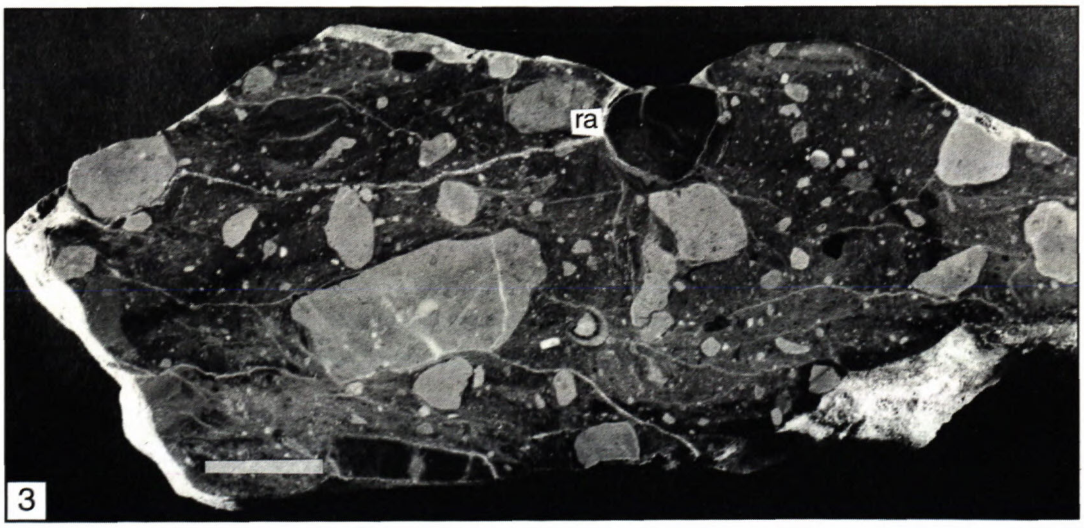

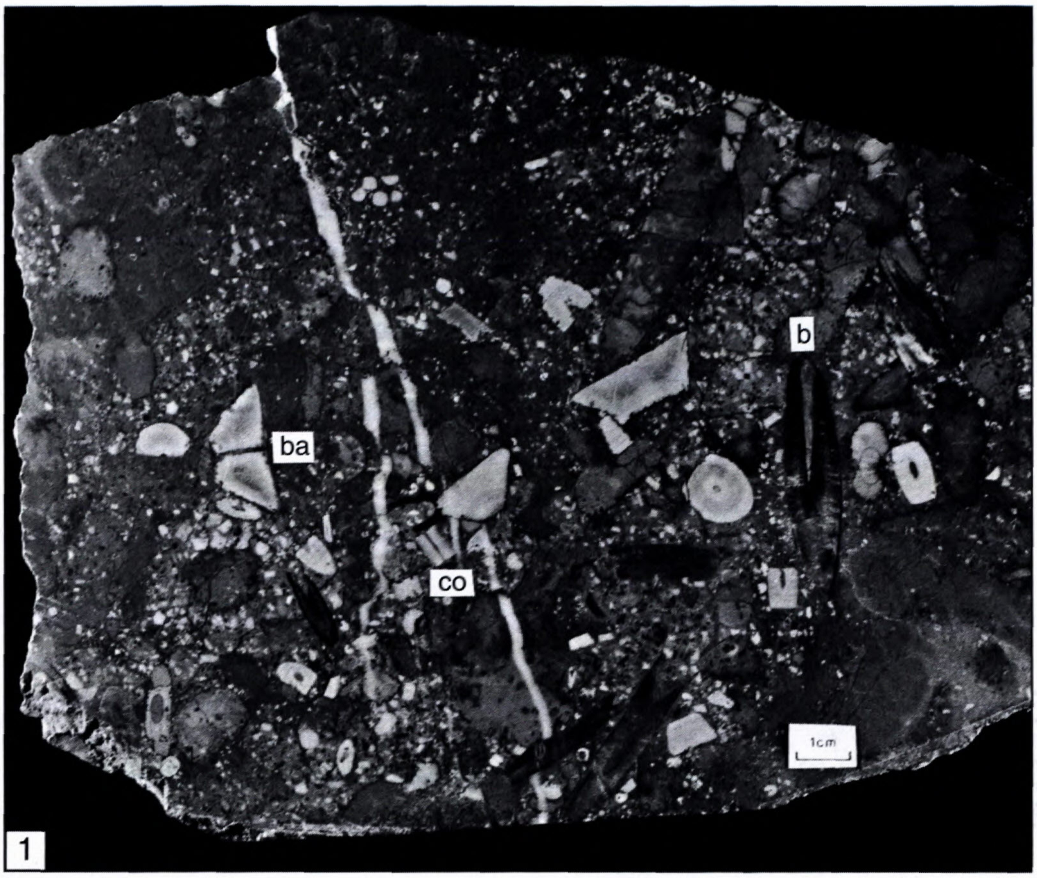
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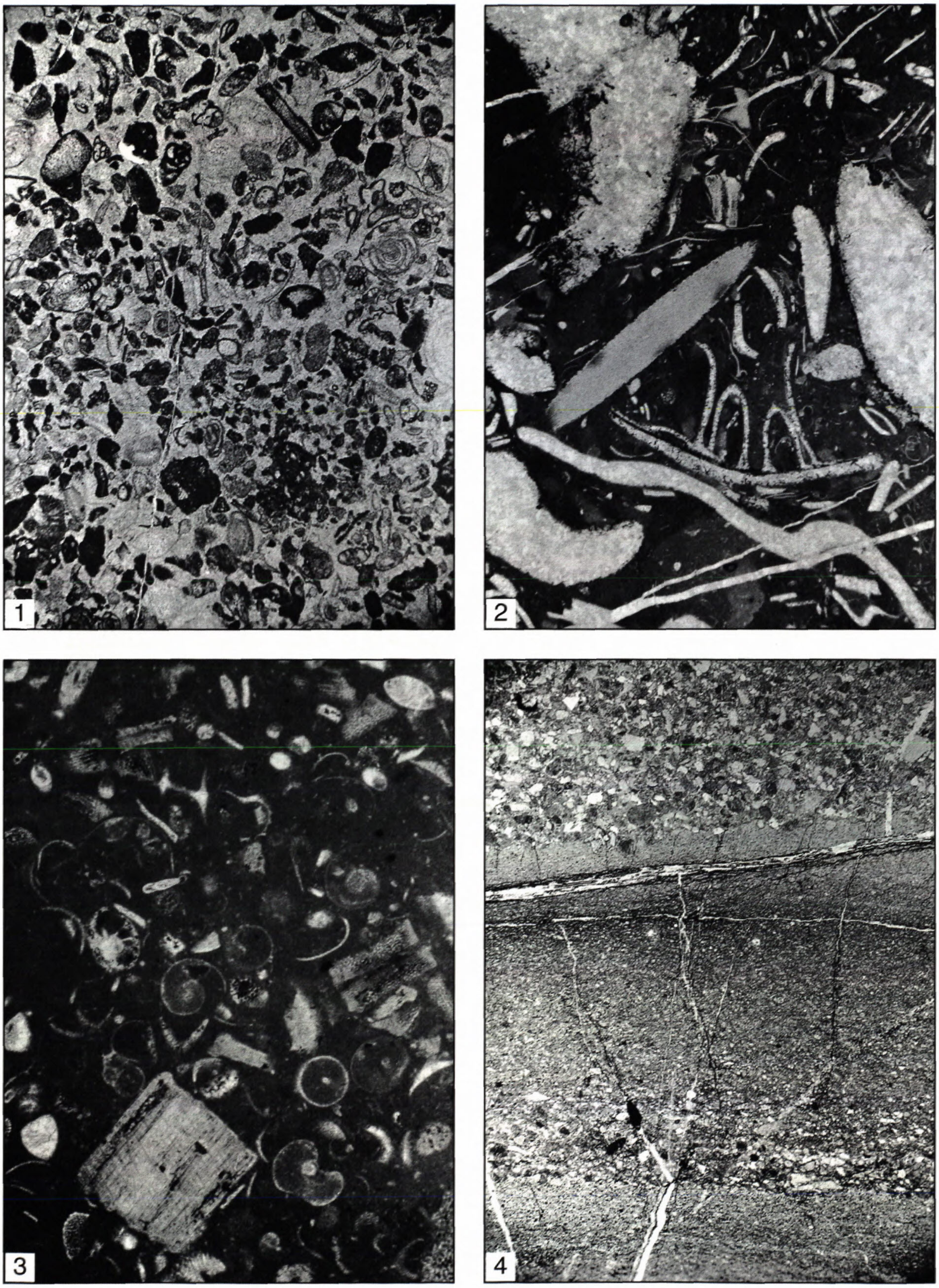

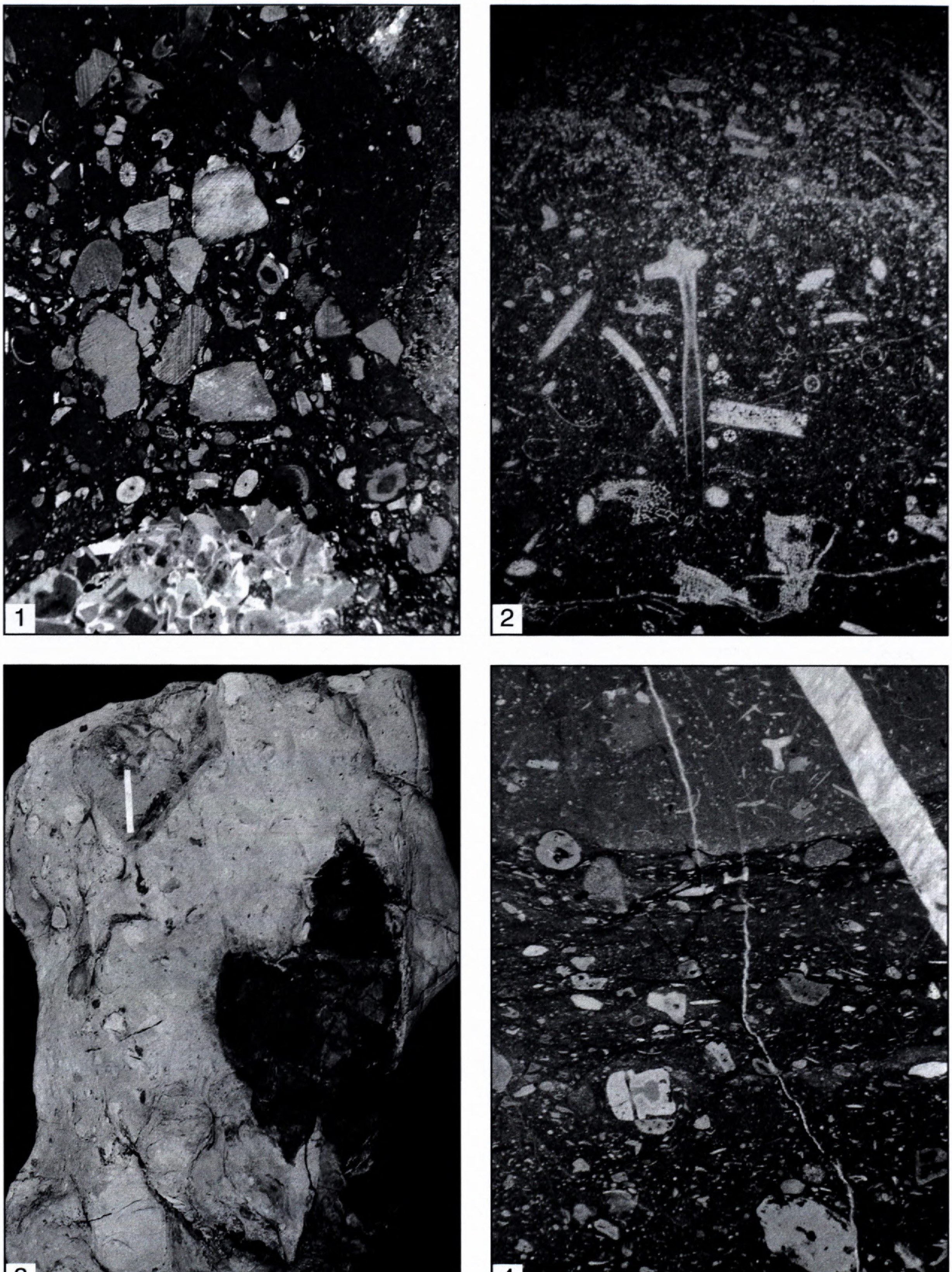
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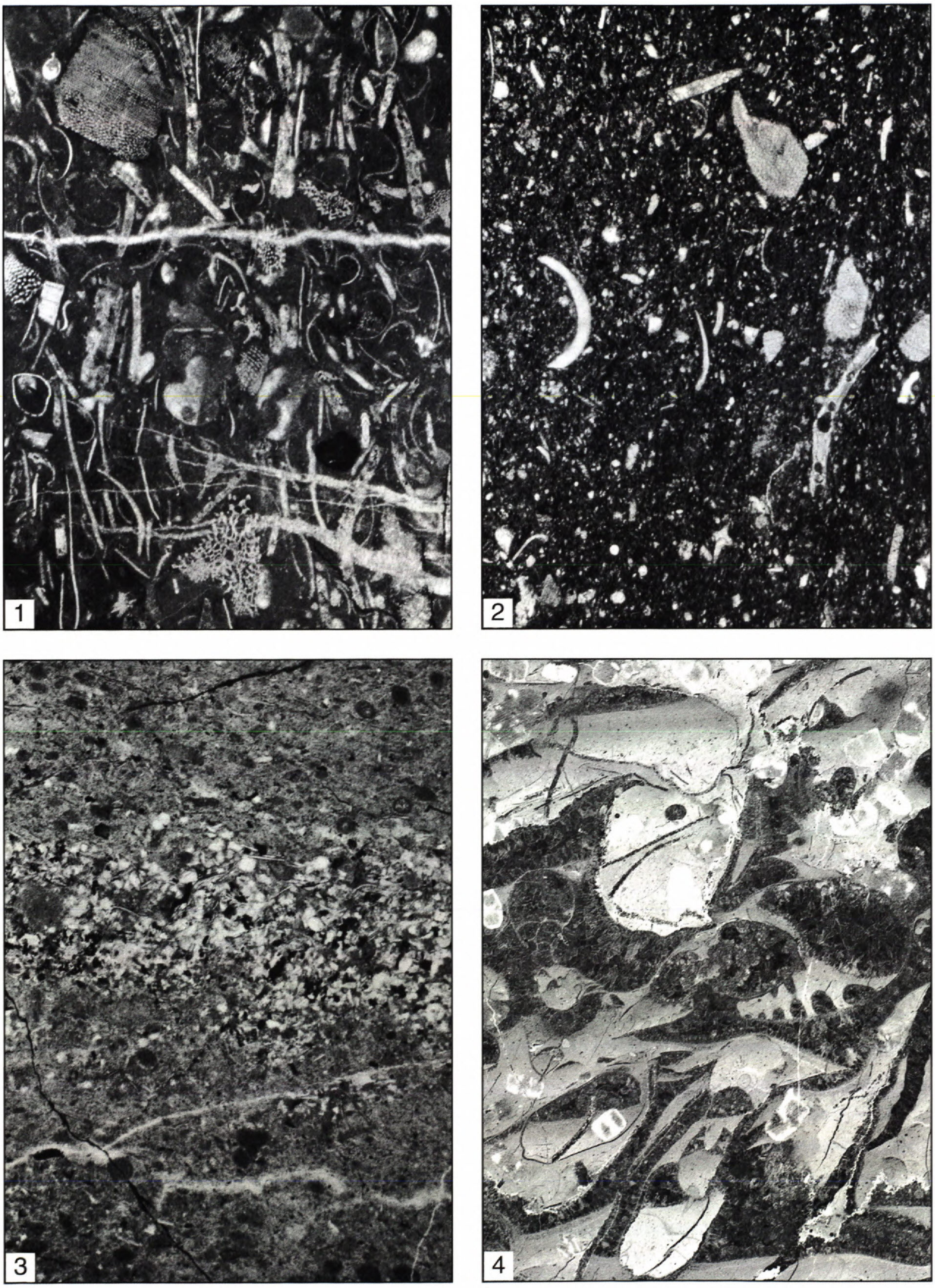
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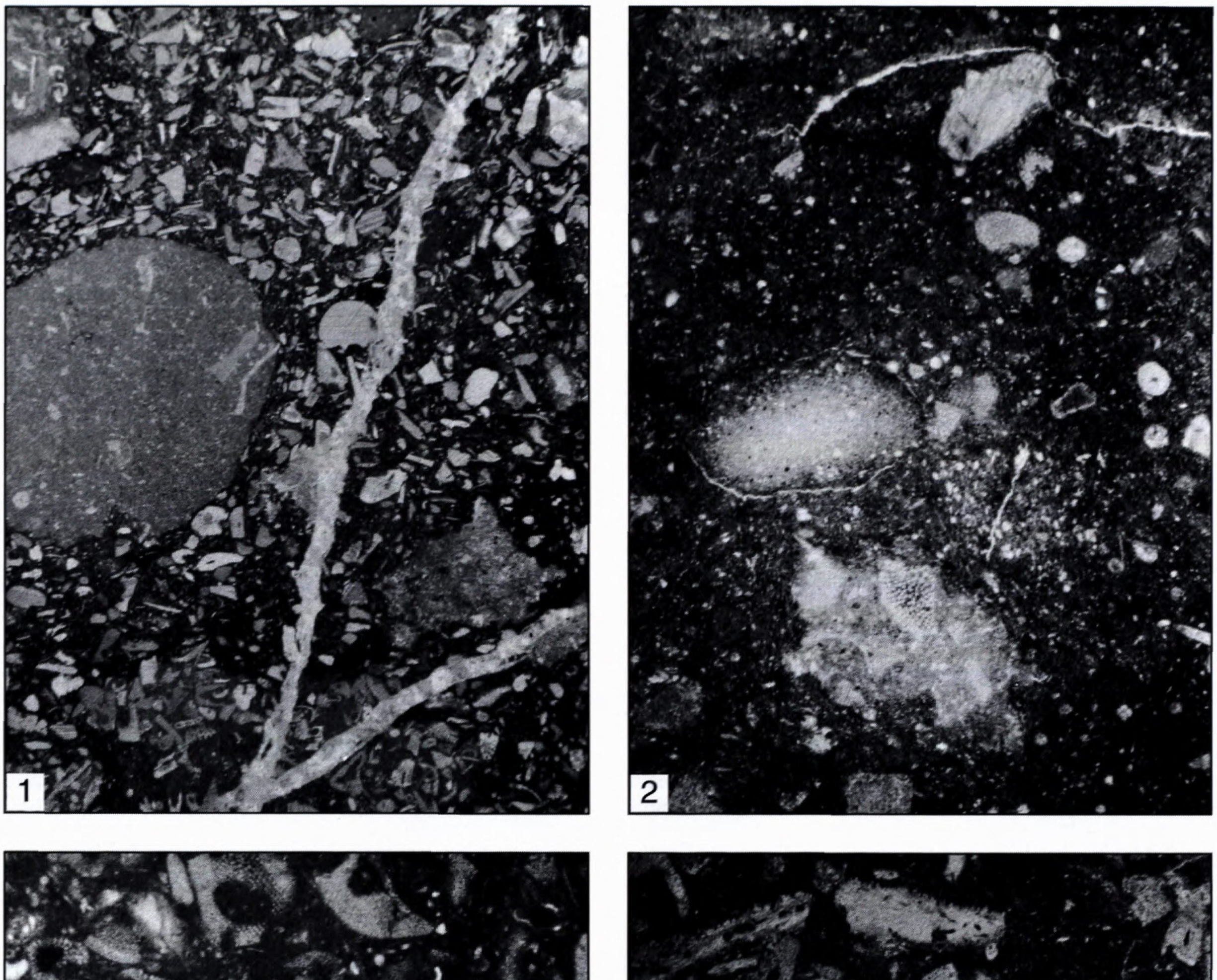
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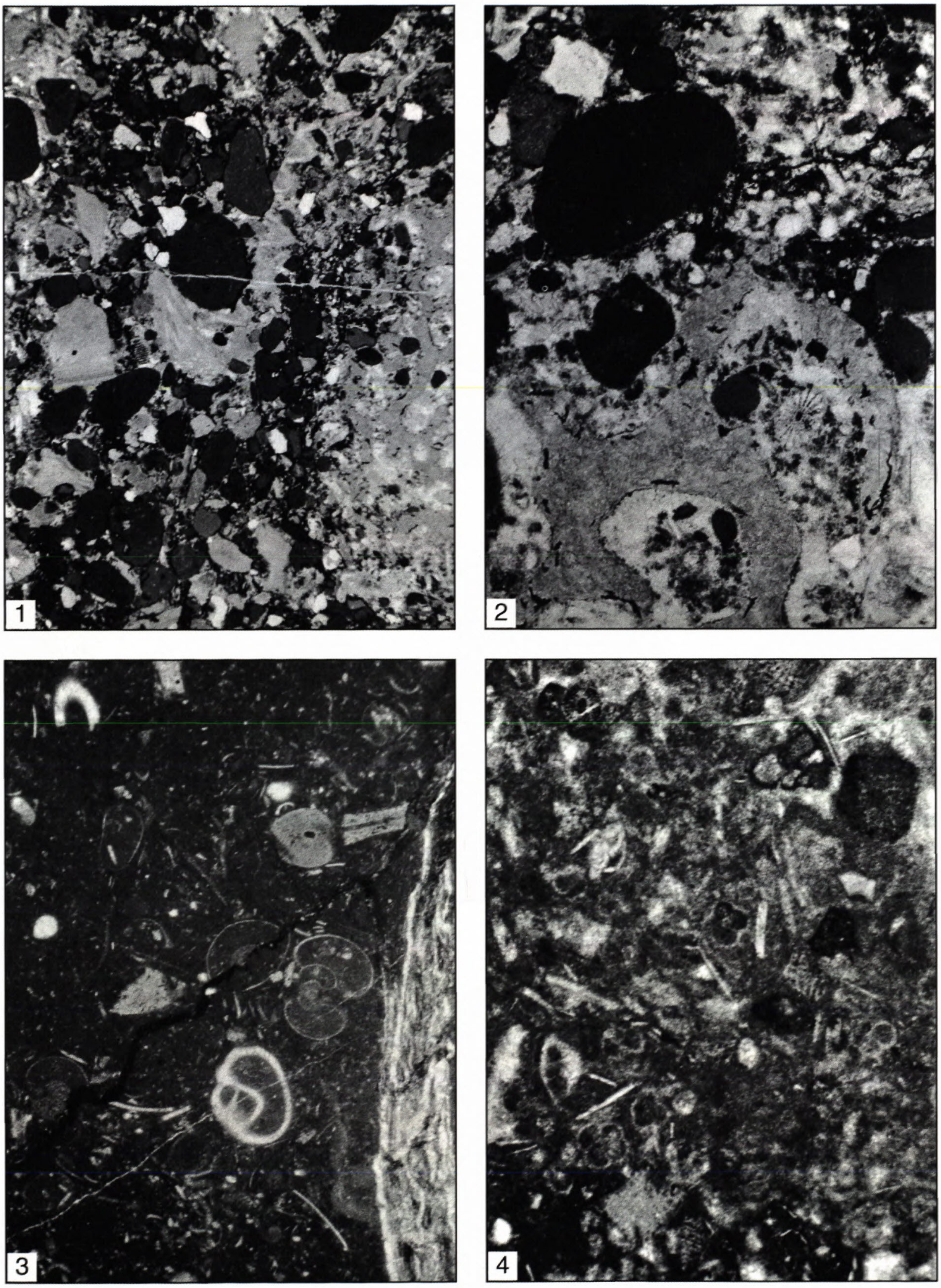
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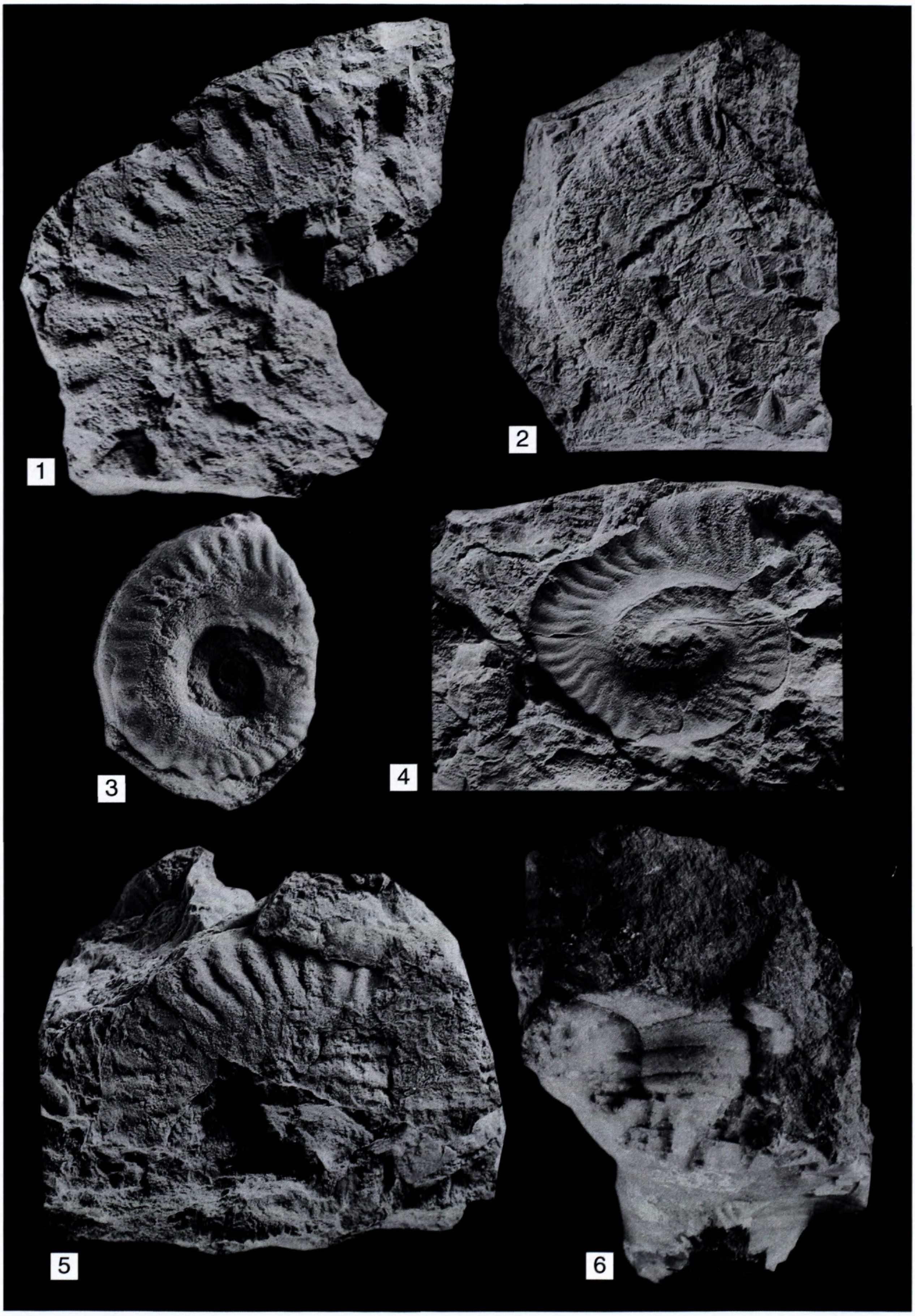
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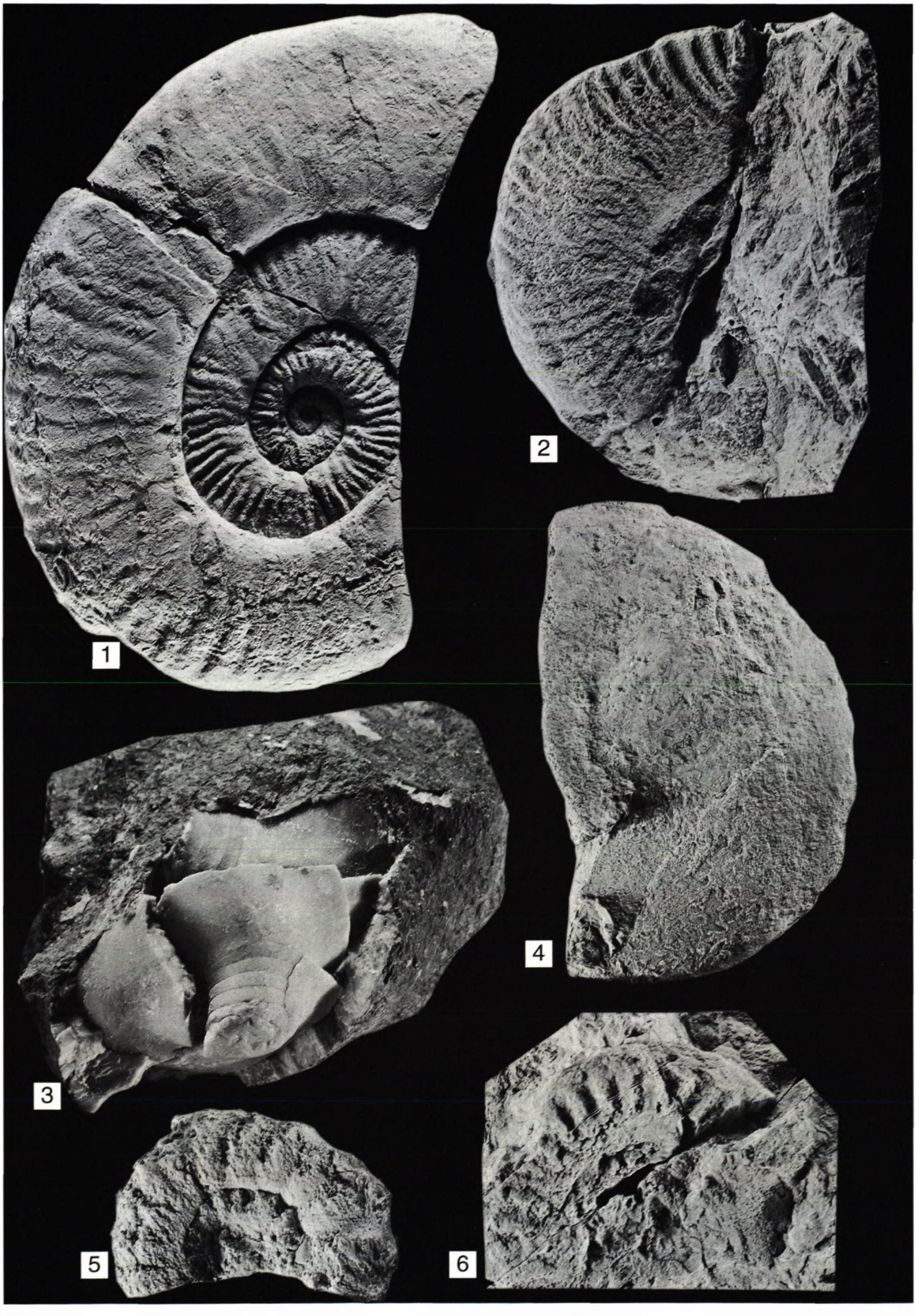
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Slovak Geol. Mag., 7, 1(2001),85–89

Lithostratigraphy of radiolarian limestones and radiolarites of the Hronicum in the Strážovské vrchy Mts.

MILAN POLÁK[1] and LADISLAVA OŽVOLDOVÁ[2]

[1]Geological Survey of Slovak Republic, Mlynská dolina 1, 817 04 Bratislava, Slovakia
[2]Department of Geology and Paleontology, Faculty of Science Comenius University, Mlynská dolina G, 842 15 Bratislava, Slovakia

Abstract. From the formation of Middle to Upper Jurassic radiolarian limestones of the Hronicum (sequence of Rohatá skala) in the Strážovské vrchy Mts. a radiolarian microfauna representing the stratigraphical range–middle Bathonian – early Callovian was obtained.

Key words: Radiolarian limestones radiolarites, microfacies, radiolarians, age, Hronicum, Strážovské vrchy Mts., Western Carpathians, Slovakia.

Introduction

In the last time in the frame of the project Tectogenesis of sedimentary basins of the Western Carpathians we have been focused on the documentation and study of the formation of radiolarian limestones and radiolarites in the Hronicum of the Western Carpathians. From this significant tectonic unit there so far has not been any direct paleontological evidence of their age as well as lithology and detailed microfacial content. This way we have obtained direct paleontological data on the stratigraphic range of this formation in the Tatricum, Krížna nappe and Hronicum, thus in the main tectonic units of the central part of the Inner Western Carpathians.

For the first time the so called series of Rohatá skala with the fundamental Jurassic members was distinguished by Kulcsár (1917, 1934). Later he assigned it to the so called limestone nappe being essentially the Choč and Strážov nappes ranged to the Hronicum at present. This sequence was later mentioned by Andrusov (1936, 1938), Mahel' (1985) described in the sequence of Rohatá skala the mentioned formation relatively in detail as „cherty limestones" and ranged them stratigraphically to the Lower – Middle Dogger.

Lithology

An almost complete profile of the formation of radiolarian limestones and radiolarites of the Choč nappe (Hronicum) of the Strážovské vrchy Mts. is creping out in the old forest path cut about 600 m southwest of the village Mojtín. Directly under-lying are grey pink crinoidal limestones, the uppermost part of which is formed by a thin layer of condensed facies of Toarcian age. Overlying are red nodular limestones of Kimmeridgian age.

The lowermost part of the profile is formed by a layer of about 90 cm thick greenish, greyishgreen, banked limestones with nodules of dark-grey radiolarites. After a short break the profile continues with red and violet banked (5–10 cm) radiolarian limestones with nodules of red radiolarites, of maximum size up to 10 cm. Thickness of this layer is about 300 cm. Above them is a passage of 300 cm thick grey weakly marly thin-banked (5 cm) limestones with nodules of black cherts. A further layer, about 200 cm thick, is formed by red, violet, radiolarian limestones with nodules and thin layers of red radiolarites. Thickness of banks varies from 5 to 10 cm. The formation continues by a layer 200 cm thick, formed by light-grey to white weakly marly, banked (10–15 cm) limestones with nodules of pink radiolarites. After a longer break of the profile defilé ends with an about 10 m thick layer of variegated (pink, red, violet, green) disintegrating radiolarites.

In texture they are prevailingly biomicrites, more rarely biomicrosparites of wackestone type. In limestones of the mentioned formation the radiolarian microfacies is mostly spread. The share of radiolarians, which are a rock-building component, varies from 40 to 85 %. The major part of radiolarians, to the contrary to most studied profiles in the Krížna nappe, is silicified, an essentially lower share of radiolarians is calcified only. On the basis of preservation of original composition also the measure of possibility of obtaining suitable micropaleontological material depends. Almost 60 % of radiolarians belong to spumellarian forms the rest is represented by nassellarians.

The form and way of preservation of radiolarians are very diverse. Often ostracodes, globochaets are present, fragments of crinoid ossicles are more rare. There are also fragments of lamellibranchs, aptychi. In the upper parts of the profile the share of filaments, detritus of aptychi, cross sections of planctonic crinoids *Saccocoma* sp. increase. The clastic admixture is present sporadically in form of angular fragments of quartz of aleuritic size category.

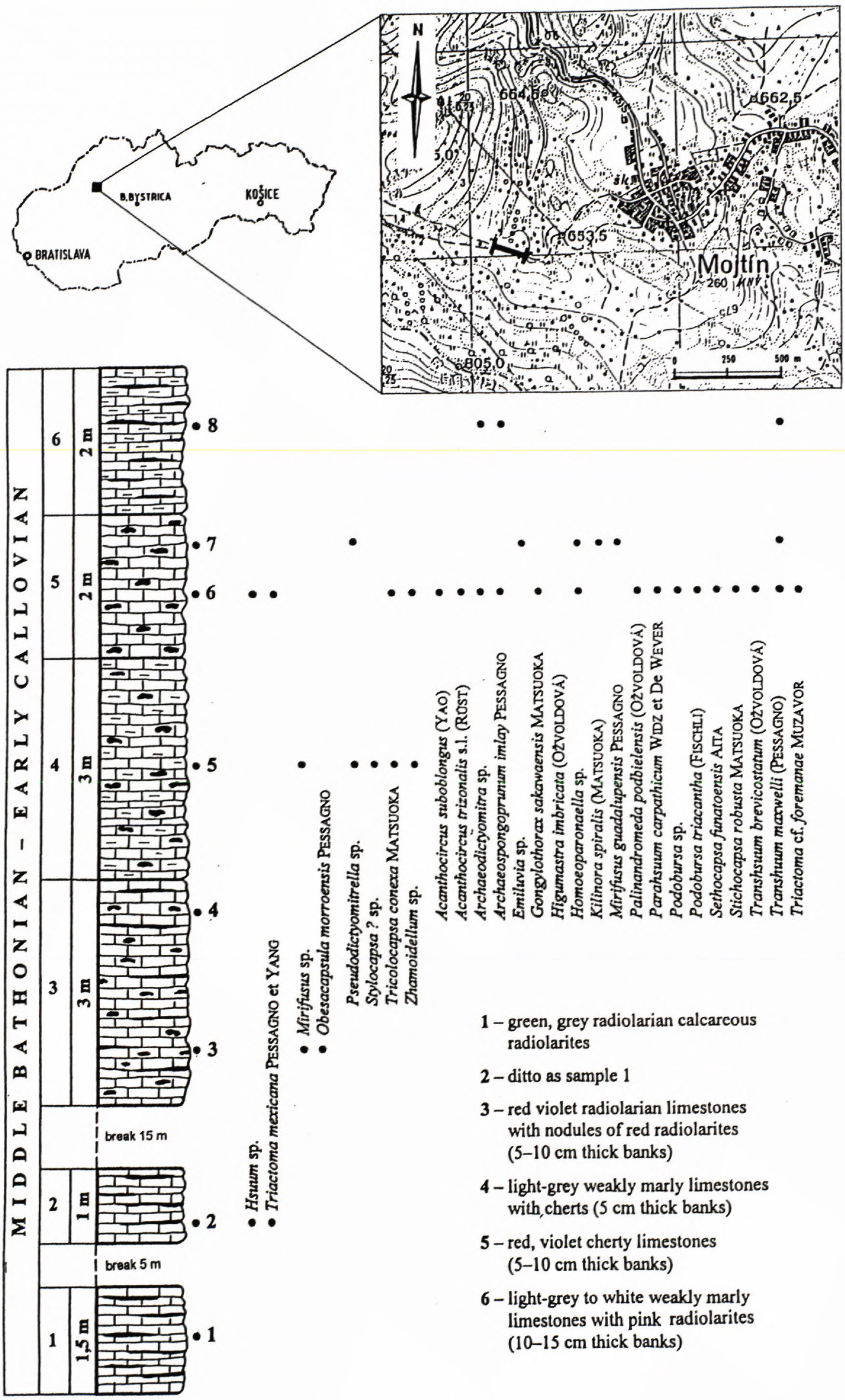


Fig. 1 Location and lithostratigraphic column of the section studied

Tab. 1 Distribution of radiolarians in the samples studied

Sample Radiolarian fauna	M-2	M-3	M-5	M-6	M-7	M-8
Acanthocircus suboblongus (YAO)				*		
Acanthocircus trizonalis s.l. (RÜST)				*		
Archaeodictyomitra sp.				*		*
Archaeospongoprunum imlayi PESSAGNO						*
Emiluvia sp.					*	
Gongylothorax sakawaensis MATSUOKA				*		
Higumastra imbricata (OŽVOLDOVÁ)				*		
Homoeoparonaella sp.				*	*	
Hsuum sp.	*			*		
Kilinora spiralis (MATSUOKA)					*	
Mirifusus guadalupensis PESSAGNO					*	
Mirifusus sp.		*	*			
Obesacapsula morroensis PESSAGNO		*				
Palinandromeda podbielensis (OŽVOLDOVÁ)				*		
Parahsuum carpathicum WIDZ et DE WEVER				*		
Podobursa sp.				*		
Podobursa triacantha (FISCHLI)				*		
Pseudodictyomitrella sp.			*		*	
Sethocapsa funatoensis AITA				*	*	
Stichocapsa robusta MATSUOKA				*		
Stylocapsa ? sp.			*			
Transhsuum brevicostatum (OŽVOLDOVÁ)				*		
Transhsuum maxwelli (PESSAGNO)				*	*	*
Triactoma cf. *foremanae* MUZAVOR				*		
Triactoma mexicana PESSAGNO et YANG	*			*		
Tricolocapsa conexa MATSUOKA			*	*		
Zhamoidellum sp.			*	*		

Radiolarites form the second distinct rock part of the formation. They predominantly are found in limestones in form of irregular ellipsoidal nodules of various size. They are almost always parallel with bedding. Often these nodules are connected, giving rise to layers and strips of radiolarites.

Radiolarites similarly as limestones are of relatively variegated colours from black, through grey, green, red and violet varieties.

From microfacial point of view we evaluate them as silicite-calcite biomicrites with a high frequency of radiolarians, prevailingly of spumellarian type, which are mainly formed by the original fine-grained quartz substance. From organic remnants there are still sporadical ostracodes and very rarely spicules of sponges are present. A characteristic feature is the prezence of idiomorphic authigenic rhomboids, formed by calcite and/or dolomite. These rhombohedrons are almost always bound to organic remnants, which usually form their central part.

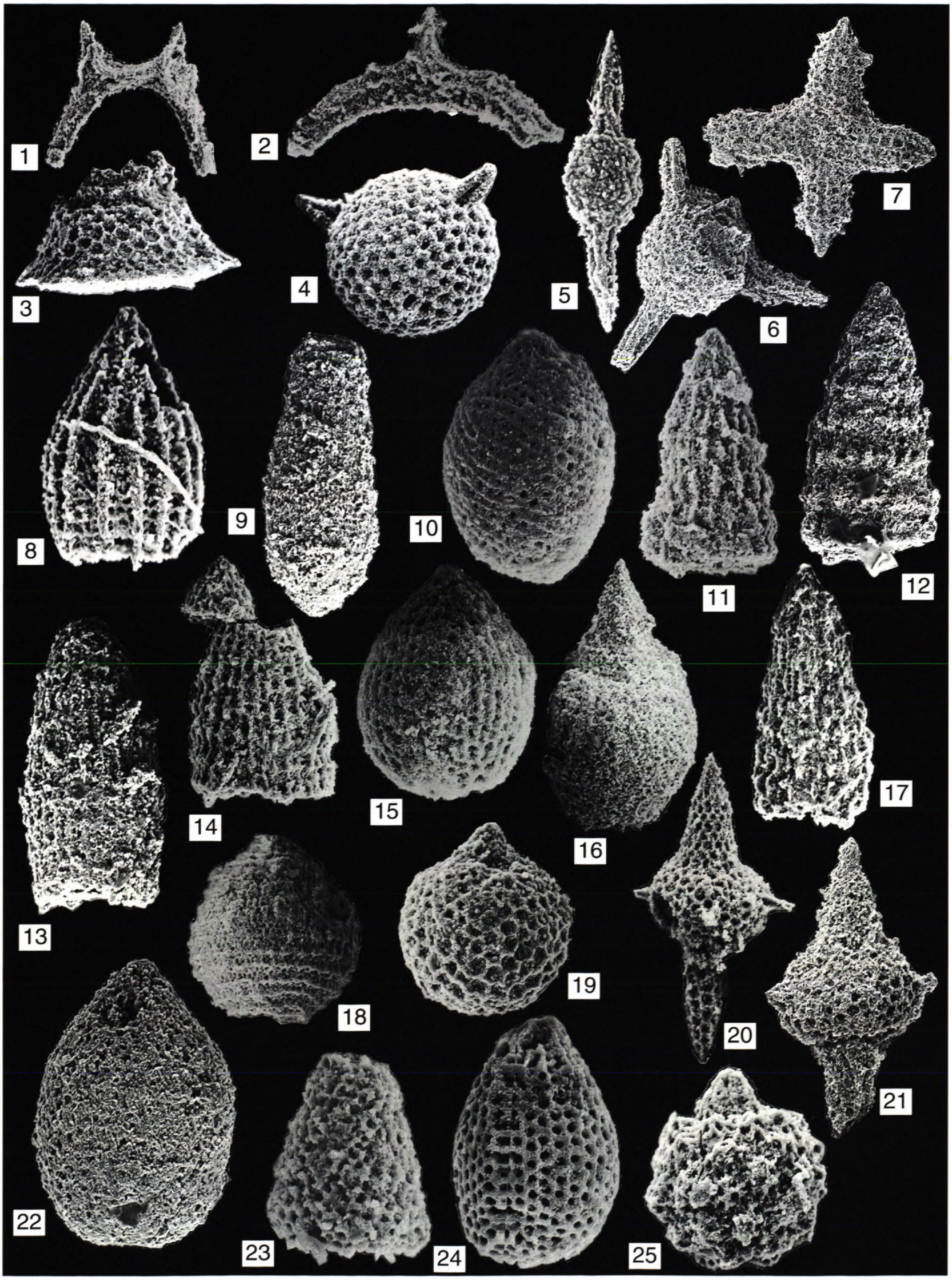
Biostratigraphical evaluation

In samples M-2/99 to M-9/99 the prevailing part of the present radiolarian microfauna was represented in form of cores only. A relatively more numerous, medium preserved microfauna, making possible to establish the range of age of the associations was found in samples M-6/99 and M-7/99 only. Also in these samples, however, the relatively considerable occurrence of cores perevented from finding out quatitative representation of the individual taxa.

In sample M-6/99 the presence of the species *Tricolocapsa conexa* MATSUOKA, *Stichocapsa robusta* MATSUOKA and *Gongylothorax sakawaensis* MATSUOKA, the occurrence of which, according to biozonation of Baumgartner et al. (1995), ends in the U.A.Z. 7 (late Bathonian – early Callovian), indicates that the associations are not younger than the Lower Callovian. The lower boundary of the range of age is given by the species *Gongylothorax sakawaensis*, which according to this biozonation starts to occur in the U.A.Z. 6 – in the Middle Bathonian.

In sample M-7/99 the occurrence of the species *Tricolocapsa conexa* MATSUOKA and *Kilinora spiralis* (MATSUOKA), which cease to be found in the U.A.Z. 7, also indicates an association not younger than the early Callovian. The lower boundary of the range is indicated by the first occurrence of the species *Kilinora spiralis* – in the U.A.Z. 6 Zone – in the middle Bathonian.

From the analysis of both associations according to the above mentioned biozonation it results that they may be ranged in their age to the stratigraphic interval – middle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Bathonian to late Bathonian – early Callovian (U.A.Z.6 – U.A.Z. 7).

According to up to present data from radiolarian research in the Western Carpathians the composition of the associations M-6/99 and M-7/99 is very similar to associations of samples B/5 and B/f to B/b from the profile at the locality Butkov (Rakús & Ožvoldová, 1999). Besides similar species composition, only at this locality the species *Kilinora spiralis* (MATSUOKA), was found (sample B/5). The difference of the associations of the studied samples essentially consisted in poorer preservation only.

In the studied associations the species *Transhsuum maxwelli* (PESSAGNO) was distinctly predominating, the numerous occurrence of which together with the species *Transhsuum brevicostatum* (OŽVOLDOVÁ) is characteristic of all associations of this stratigraphic range in the Pieniny Klippen Belt. In relatively less amount specimens of the genus *Podobursa* are found.

The composition of microfauna in the individual samples is mentioned in Tab. 1. Besides radiolarian microfauna the sample M-5/99 contained the form *Globuligerina* sp.

The best preserved forms in the associations are figured in the enclosed photographic plate.

Conclusion

For the first time the age of radiolarian limestones and radiolarites in the Choč nappe (Hronicum) of the Western Carpathians was established by direct paleontological methods.

From red radiolarian limestones and radiolarites a radiolarian microfauna was obtained, which according to biozonation points to the stratigraphical interval – middle Bathonian to late Bathonian – early Callovian (U.A.Z. 7).

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Pl. I

Fig. 1 – *Acanthocircus suboblongus* (YAO) – M-6, 0113, 130x; 2 – *Acanthocircus trizonalis* s.l. (RÜST) – M-6, 0125, 150x; 3 – *Palinandromeda podbielensis* (OŽVOLDOVÁ) – M-6, 0122, 110x; 4 – *Triactoma mexicana* PESSAGNO et YANG – M-2, 0109, 110x; 5 – *Archaeospongoprunum imlayi* PESSAGNO – M-8, 0132, 135x; 6 – *Triactoma* cf. *foremanae* MUZAVOR – M-6, 7001, 120x; 7 – *Higumastra imbricata* (OŽVOLDOVÁ) – M-6, 7002, 105x; 8 – *Hsuum* sp. – M-2, 0110, 195x; 9 – *Gongylothorax sakawaensis* MATSUOKA – M-6, 7018, 300x; 10 – *Kilinora spiralis* (MATSUOKA) – M-7, 0136, 330x; 11 – *Transhsuum maxwelli* (PESSAGNO) – M-6, 0124, 195x; 12 – *Transhsuum brevicostatum* (OŽVOLDOVÁ) – M-6, 7017, 250x; 13 – *Archaeodictyomitra* sp. – M-6, 7016, 400x; 14 – *Parahsuum carpathicum* WIDZ et DE WEVER – M-6, 0111, 175x; 15 – *Tricolocapsa conexa* MATSUOKA – M-6, 0137, 29x; 16 – *Obesacapsula morroensis* PESSAGNO – M-3, 0105, 125; 17 – *Transhsuum maxwelli* (PESSAGNO) – M-6, 0112, 160x; 18 – *Mirifusus guadalupensis* PESSAGNO – M-7, 0133, 120x; 19 – *Zhamoidellum* sp. – M-6, 0128, 195x; 20 – *Podobursa triacantha* (FISCHLI) – M-6, 0120, 150x; 21 – *Podobursa* sp. – M-6, 7005, 180x; 22 – *Stichocapsa robusta* MATSUOKA – M-6, 7006, 300x; 23 – *Pseudodictyomitrella* sp. – M-5, 0100, 300x; 24 – *Stylocapsa* ? sp. – M-5, 0103, 350x; 25 – *Sethocapsa funatoensis* AITA – M-6, 0129, 220x.

On the find of Triassic brachiopod fauna in the variegated micrites on the Dachstein Plateau

Miloš Siblík

Institute of Geology, Academy of Sciences of the Czech Republic, Rozvojová 135, 165 00 Praha 6 – Suchdol

Abstract: Triassic age of the variegated micritic marly limestones sporadically occurring in the Dachstein Formation on the Dachstein Plateau SSW of Hallstatt was documented with the finds of Upper Triassic terebratulid *Triadithyris gregariaeformis* (Zugmayer, 1880) and of remains of dasycladacean algae.

Key words: Northern Calcareous Alps, Triassic, Dachstein Formation, brachiopods

Introduction

Rich Liassic brachiopod fauna is well-known from white and red biosparitic fissure-fillings in the monotonously grey Dachstein Limestone on the Dachstein massif SSW of Hallstatt and it was described in detail already many years ago (e.g. from Hierlatz by Oppel, 1861 and Geyer, 1889). The present study was prompted by the discovery of biplicate terebratulid brachiopods occurring not far from Hierlatz in the yellow, reddish, ochrous or greenish micrites which form irregular spots – not fissure fillings – in the Dachstein Limestone on the Plateau, S of the Wiesberghaus. In 1991 I happened to find the first locality, following years 3 other localities were ascertained in the vicinity of the touristic path from the Wiesberghaus towards the Simonyhütte yielding always the same, only one determinable terebratulid species, the only one determinable macrofossil in these variegated micrites. The age of micrites was questionable, because biostratigraphic information on them was missing at that time. They reminded oneself externally of similarly variegated Lowermost Liassic carbonates of other areas of the Northern Calcareous Alps. The terebratulid species under consideration was studied and determined as *Triadithyris gregariaeformis* (Zugmayer). In the locality 3 only, 25 small (up to 9.0 mm long) mostly fragmentary juvenile specimens of undeterminable flat zeileriids (?) were found except for *Triadithyris gregariaeformis*, showing rectimarginate anterior commissure, clear dental lamellae and dorsal septum. *Triadithyris gregariaeformis* had been described by Zugmayer in 1880 from the Rhaetian of the Piesting Valley near Vienna, and its lectotype designated later by Pearson (1977) came from the Kaisersteffel near Waldegg. However, this species was mentioned in the older literature also from the Lower Liassic (e.g. by Vigh, 1961 -- not newly revised), and so the uncertainty about the age of the micrites under consideration remained.

Samples kindly taken by Dr. G. Mandl (Wien) for conodonts (with negative results) and by Dr. H. Lobitzer (Wien) for microfacies did not help much to tell anything more about the age of the carbonate matrix. Nevertheless, from the geological point of view both these colleagues were rather sceptical as to the Liassic age of the rock (personal communications). According to Lobitzer, the micritic marly limestones are equivalents of Member A sensu Fischer (1964). At studied outcrops typical Lofer cycles are not developed but surrounding Dachstein Limestone is clearly of lagoonal origin and nearby various types of complete or „amputated„ Lofer cycles can be observed. Maybe most of the micritic sediment is of pedogenic origin with temporary influence of marine sedimentation (Lobitzer, written communication). Recently, 4 thin sections of the micrite coming from the locality 4 were kindly examined by Dr. O. Ebli (München). According to him, they were nearly barren of microfossils and very rare foraminifers were represented mainly by stratigraphically not important *Lagenidae*. Of great interest was, however, his find of dasycladacean algae (? *Salpingoporella*?). This was an

Fig. 1 Situation map of the area S of the Wiesberghaus showing 4 localities of variegated micrites with brachiopod fauna (ÖK 96 Bad Ischl).

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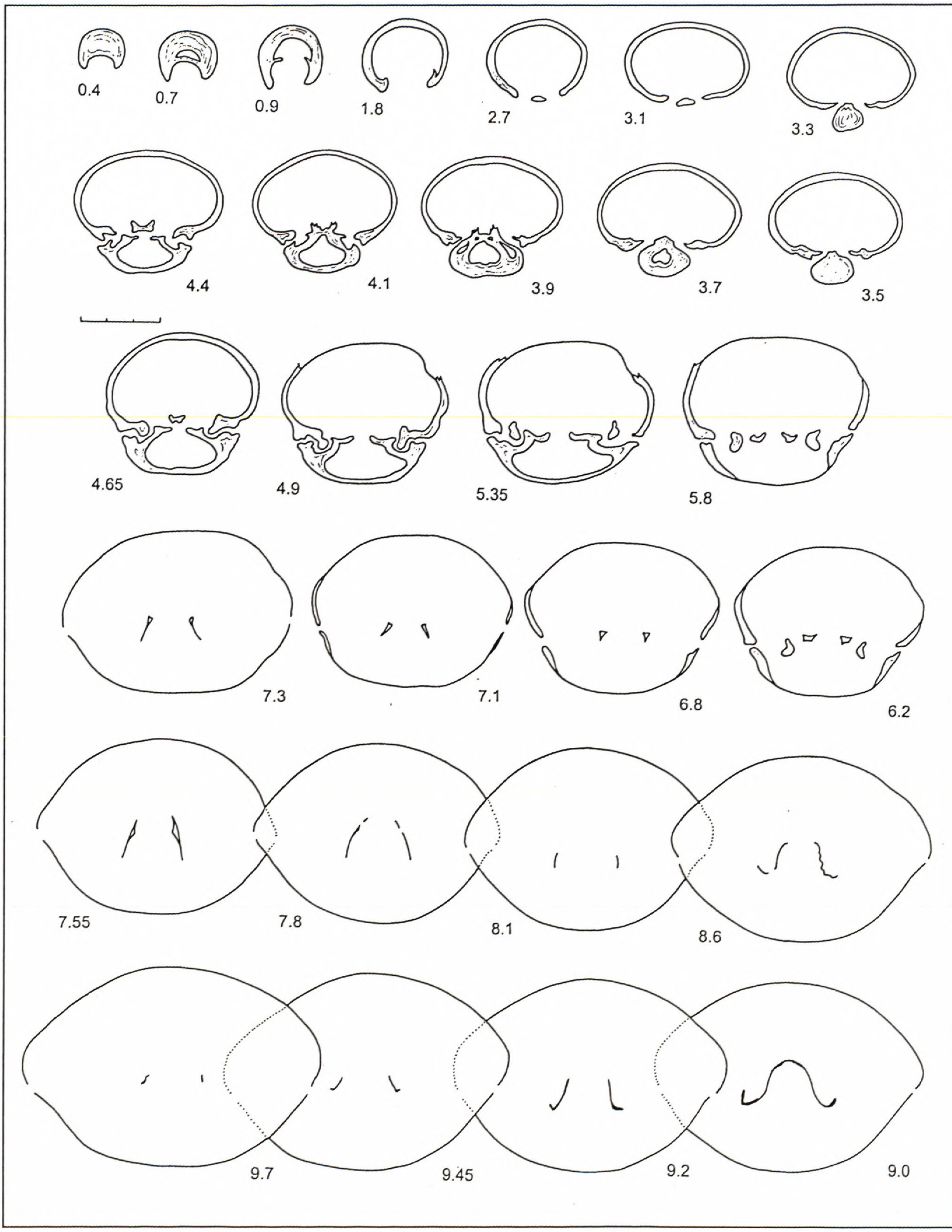

Fig. 2 Triadithyris gregariaeformis (ZUGMAYER). S of Wiesberghaus, locality 2. Serial transverse sections through the posterior part of shell. Total length of specimen 18.0 mm. Enlarged, scale bar equals 3 mm.

important hint for the Triassic age of the sample, because green algae are not known to occur in the Alpine Liassic. According to Ebli (written communication), the find of green algae in the thin section together with the geological situation dates the sampled lithology as Triassic.

Palaeontological part

Order:	Terebratulida WAAGEN, 1883
Superfamily:	Loboidothyridacea MAKRIDIN, 1964
Family:	Loboidothyrididae MAKRIDIN, 1964
Genus:	*Triadithyris* DAGYS, 1963

Triadithyris gregariaeformis (ZUGMAYER, 1880)
(Text-Figs. 2 - 3)

1880 *Terebratula gregariaeformis* n.f. - ZUGMAYER, p. 13, Pl. 1, Figs. 22, 26-29.
1977 *Triadithyris gregariaeformis* (ZUGMAYER) - PEARSON, p. 44, Text-Figs. 14-16, Pl. 7, Figs. 11-14 (cum syn.).
1988 *Triadithyris gregariaeformis* (ZUGMAYER) - SIBLÍK, p. 103.
1998 *Triadithyris gregariaeformis* (ZUGMAYER) - SIBLÍK, p. 84, Pl. 3, Fig. 5 (cum syn.).

Material: 246 mostly fragmentary specimens up to 20.0 mm long, 21.0 mm wide and 13.2 mm thick. The figured specimens measure: 15.2 x 13.4 x 8.4 mm (Text-Fig. 3, Figs. 1 A-C), 18.5 x c.18.8 x 10.2 mm (Text-Fig. 3, Figs. 2 A-C) and 16.4 x 16.5 x 8.1 mm (Text-Fig. 3, Figs. 3 A-C).

Occurrence: Dachstein Plateau, S of the Wiesberghaus: Locality 1 (14 specimens), locality 2 (186 specimens), locality 3 (3 specimens) and locality 4 (43 specimens). The species is not very frequent in the Northern Calcareous Alps (Pearson, 1977, p. 44). It is known from the Rhaetian of Austria (Siblík, 1988); from the Dachsteinkalk it was reported e.g. already by Bittner (1890, p. 278 -- locality in the Steinernes Meer near Saalfelden). Recently it was ascertained in the „Oberrhätkalk„ of Steinplatte (Siblík, 1998). The species is known from the Norian-Rhaetian in other countries, it is common e.g. in the Sevatian locality Drnava in Slovakia.

Remarks: Nothing substantial is to be added to the detailed descriptions given by Zugmayer (1880), Dagys (1963) and Pearson (1977).

Because of the problem of external homoeomorphy, it is not easy to determinate biplicate terebratulids described in the literature from near of the Triassic/Jurassic bound-

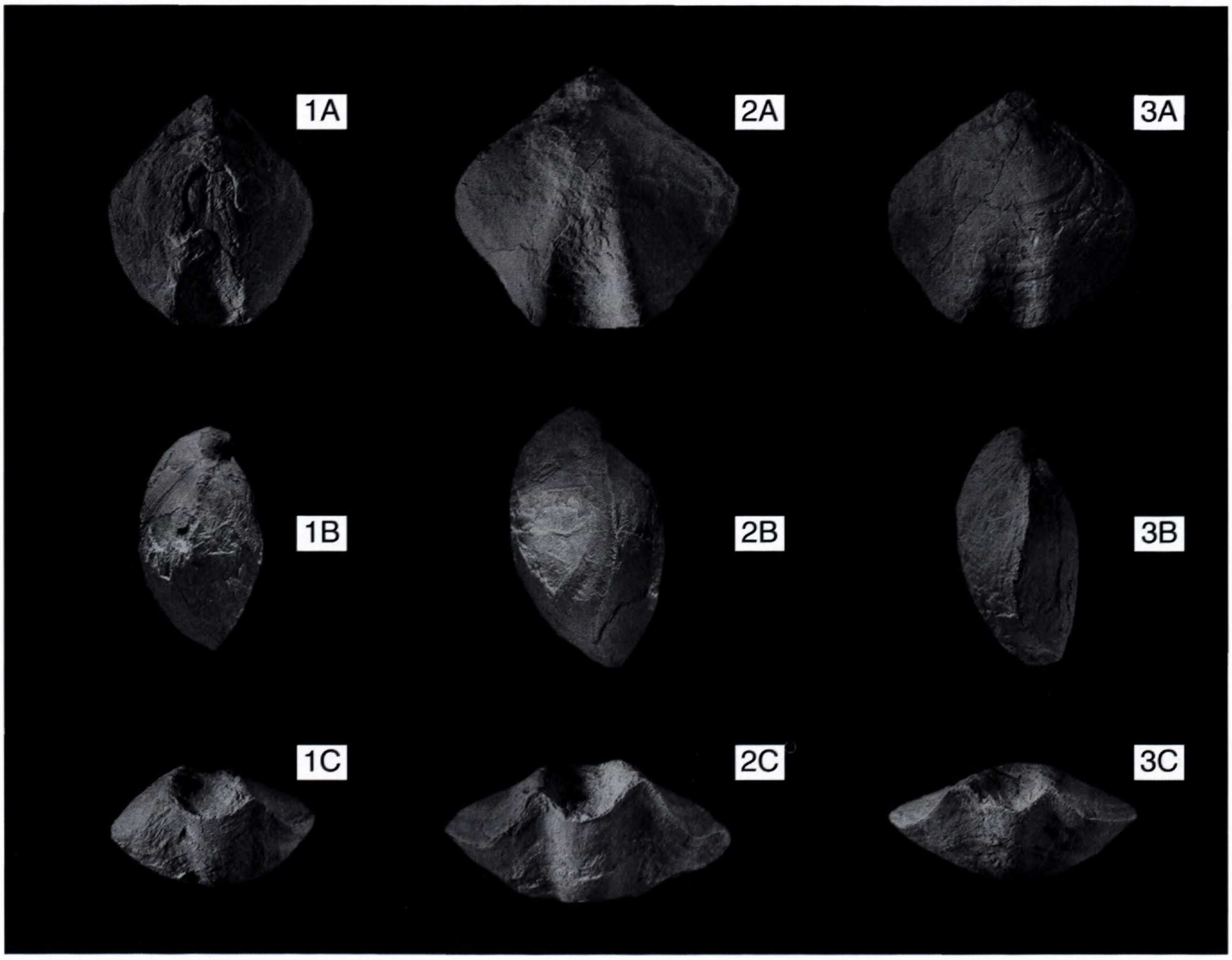

Fig. 3 Triadithyris gregariaeformis (ZUGMAYER). S of Wiesberghaus.
1 A-C: locality 1. GBA No. 2000/29/1; 2 A-C: locality 2. GBA No. 2000/29/2; 3 A-C: locality 4. GBA No. 2000/29/3.
All magnified, x 2. Collections of the Geologische Bundesanstalt Wien. Photo by Mr. J. Brožek (Prague).

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ary, and it is difficult to speculate on their generic attri butions without knowledge of the internal characters. External similarity of *Triadithyris gregariaeformis* and *Rhaetina gregaria* (SUESS) is well known, their internal structures are quite different, however. *Rhaetina* WAAGEN, 1882 is externally homoeomorphic with *Pseudorhaetina* SANDY, 1994 (type species *P. antimoniensis* SANDY, 1994 from the Norian of Mexico) but they have different internal structures, esp. another shapes of brachidia and hinge plates. On the other hand, *Pseudorhaetina* can be distinguished internally from *Triadithyris* by its high crural processes and flattened top of transverse band; a cardinal process has not been ascertained in *Pseudorhaetina.* Another biplicate species which should be mentioned here, is „*Terebratula*„ *subgregaria* n.f. described by Dal Piaz (1909, p. 6, Pl.1, Fig. 3) from the Sinemurian of the Southern Alps. This species was ascertained some years ago in the Hettangian of the Bakony Mts. (Hungary) by Dulai (1993), and basing on the internal sections determined as *Lobothyris* ? *subgregaria* (DAL PIAZ). This species differs externally from average specimens of *gregariaeformis* and *gregaria* in its suboval outline, larger beak, and wider and shallower biplication.

In the older literature, there were some suggestions that *Rhaetina gregaria* (SUESS) is not restricted to the Rhaetian only, and ranges into the Earliest Liassic (e.g. Parona, 1884; Fucini, 1895; Geyer, 1889; Trauth, 1909; specimen figured in Raileanu & Iordan, 1964 = ? *Lobothyris subgregaria* ?). In most cases, these data have been neither revised nor proved recently. Geyer (1889) described and figured this species from the Lower Liassic of Hierlatz. Pearson (1977) refigured 3 Geyer's specimens from Hierlatz and made also serial sections of his another specimen which documented its *Rhaetina* character. The same was confirmed by my study of the internal structures made in 2 specimens from Geyer's collection from Hierlatz deposited in the Geologische Bundesanstalt in Vienna. It is of particular interest to notice that during our thorough samplings in the last years on Hierlatz, we have not still found any specimen of *Rhaetina gregaria.* The study of the interesting sedimentological situation on Hierlatz is in progress and it is clear that neptunian dykes are there infilled with material of at least 2 different ages (at least of Sinemurian and Pliensbachian ages). It cannot be thus excluded that Geyer's specimens of *Rhaetina gregaria* came from a separate Rhaetian fissure-filling on Hierlatz (maybe contemporaneus with the near-by variegated micrites with *Triadithyris gregariaeformis*) and were afterwards mixed with the other (Liassic) samples from Hierlatz. It seems to me that so far reported occurrence of *Rhaetina gregaria* within very rich Lower Liassic brachiopod fauna on Hierlatz cannot be still taken for granted, and taken as an important proof for *gregaria*'s occurrence in the Liassic.

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Proposals for the national ProGEO list of Geological Heritage

[1]PAVEL LIŠČÁK and [2]MILAN POLÁK

Geological Survey of Slovak Republic, Mlynská dolina 1, 817 04, Bratislava, Slovakia
E-mail: [1]liscak@gssr.sk, [2]polak@gssr. sk

Abstract: The rich geological heritage of Slovakia, due to its position on the contact of Alps and Carpathians, has made this area one of the most important core regions for geological teaching and research. The creation of data bank of the geosites network conservation is the essential step towards the protection of natural areas and sites of both scientific and educational geological importance.

Key words: geological heritage of Slovakia, ProGEO, geosites, protection.

Introduction

The Geological Heritage, a non-renewable natural resource, allows us to recognise, study and interpret the geological history of the Earth and of the processes involved. At the start of the new millennium, the protection and conservation of the Geological Heritage – an important element of both our Natural and our Cultural Heritage – still raise important issues of all sorts: scientific, legal and administrative, management and representation. All these issues should be dealt globally, because the geological setting do not respect national borders or any other administrative limits.

At present, the only one potentially world designation for geological site protection is a World Heritage Site Status. World Heritage work has to date lacked any framework for the consideration of geological proposals. The conclusions of the Belogradchik workshop June 1998 and of the methodology in general, to WH may be summarised, as follows.

Geosites

1. Formation of network of informants in countries
2. Definition of key regional geo(morpho)logical elements
3. Selection of Geosites in such frameworks
4. Selection of a Geosites list for each country
5. Country selection of European WH
6. Comparative documentation of Geosites
7. Proposal of WH sites by countries

In 1995, at its Sigtuna conference, ProGEO decided to compile an European list of significant geosites. The purpose of such a list was seen as promoting geoconservation, providing a focus for cross-border collaboration, and an actual mechanism to push the process of site identification (and protection) in those countries as yet with no inventory.

In 1995 the International Union of geological Sciences decided, subsequently with the support of UNESCO, to promote a new project to compile a global inventory and related database. The president of IUGS wrote to all national committees and affiliated bodies to enlist their support for the project in 1996. IUGS has set up a new Global Geosites Working Group to undertake the work, an ProGEO has agreed to act as its agent in Europe.

Further workshops (1996 Roma, 1997 Tallin, 1998 Krakow, Prague, 2000) have set the methods for both identification of geosites and creating of single databases.

A lot of work has been done in Slovakia within the the study of its geological settings through the 20th century. Numerous papers and scientific works aid to the geological knowledge of our country. This paper is not aiming to list all of them.

Now we have reached the first stage of Geosite identification. Our national group has started to both identify their frameworks and to make choices of site areas (Wimbledon et al., 1998). Such identification will operate through two mechanisms: one by national groups and regional groupings of country participants, and secondly through specialist contributors providing a wider international perspective, on, for instance, fossils and minerals, or the history of science.

In selecting of national geosites we have to find a way how to overcome and to see through the complexity of the geological record and the numerous of localities. We have to justify what is special and representative for each country taking into account its regional geological setting.

To fulfil these demands, we have to set a national group to take the work forward. This paper ought to be perceived as an invitation for a wide national discussion on our national geosites, with enough specialists from relevant disciplines. We hope, that the best advice will be obtained through exchange and discussion amongst researchers.

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Draft List on Slovak Geological Heritage

PALEOZOIC

Stráňanský Potok valley, Malá Fatra Mts., Stráňanský Potok Fm.
Tatricum - autochthonous unit, continental-alluvium sediments of braided rivers. Cyclically arranged sediments – coarse-grained diagonal-bedded sandstones-sandy conglomerates with a partial fine-grained uppermost member. *Upper Permian*
Zelená Dolina valley, Nízke Tatry Mts., Starohorské vrchy Hills
Northern Veporicum Špania Dolina Fm. autochthonous unit. Braided stream deposits composed of graded bedded coarse-grained sandstones and sandy conglomerates with dominant arcosic material, sporadically volcanoclastic horizons, *Upper Permian*
Bystrô valley, Veporské Vrchy, Čierťaž Mts., Brusno and Predajná Fms. (Ľubietová Group)
The type profile of the Brusno Fm. – Dominant arcosic sediments of psephitic to psammitic grade and the presence of a volcanic horizon in its middle part (Harnobis horizon), Predajná Fm. – complex of clastic sediments (conglomerates, sandstones, sandy shales) – megacyclic sequence with vertical and lateral changes in lithofacies, varied colours of sediments, *Lower - Upper Permian*
Road Krokava – Burda – Slatviná, Veporské vrchy Mts., Revúcka vrchovina Upland and Rimava Fms. (Revúca Group), Southern Veporicum. It represents the upward-coarsening sequence with mutual transition from delta-shallow water to continental, fluvial association. Alpine ages of the contact metamorphism are dated acc. Rb/Sr, U/Pb, K/Ar. The climax of the contact – thermal metamorphism determined by mineral thermobarometer LP/HT. Microflora *Stephanian C-D to Permian*
Nižná Boca, Nízke Tatry Mts., Nižná Boca and Malužiná Fms. (Ipoltica Group of the Hronicum allochthonous unit)- regressive clastic sequence — medium to fine grained sandstones to siltstones and claystones. Syngenetic dacite, andesite volcanism. Macroflora and microflora – *Stephanian B-C*
Ipoltica valley, Nízke Tatry Mts., Malužiná Fm. - typical red beds with alternation of conglomerates, sandstones and shales, locally there occur layers of dolomites, gypsum and caliche. Important phenomenon is a polyphase synsedimentary andesite-basalt volcanism of continental tholeitic magmatic type. Microflora – *Lower to Upper Permian*
Ochtiná magnesite quarry, Spišsko - gemerské rudohorie Mts., type loc. of Ochtiná Fm, Northern Gemericum, allochthonous unit. Flysh-like clastic sediments – metaconglomerates, metasandstones, metapelites, interlayered with metabasalts and basaltic metavolcanoclastics, in the upper part of Fm. are neritic and littoral dolomitic shales, dolomites, magnesites. *Visean – Serpukhovian.*
Dobšiná, Biengarten quarry, Spišsko-gemerské rudohorie Mts., Zlatník Fm.
Shallow water foreshore carbonate horizon of the basal part of the Zlatník Fm. very rich on fragments of fauna, fine-grained clastic metasediments associated with fine basaltic metavolcanoclastics and scarce effusions of high-K tholeiitic basalts. *Westphalian B-C*
Závadka quarry, Spišsko-gemerské rudohorie Mts., Rudňany Fm.
Polymict boulder conglomerates, conglomerates, sandstones interpreted as delta-fan deposits. From conglomerates 34 petrographic rock types have been described. *Westphalian*
Závadka, Spišsko-gemerské rudohorie Mts., Knola Fm. of the basal part of the Krompachy Gr.
Variegated thick-bedded conglomerates of an alluvial fan environment are structurally and mineralogically immature. More then 15 petrographic types of rocks have been described from the pebble material. *Lower Permian*
Petrova Hora Hill quarry, Spišsko-gemerské rudohorie Mts., Petrova Hora Fm.
Andesites and rhyolitic ignimbrites. Synsedimentary volcanites correspond to calc-alkaline magmatic trend. Prevalent volcanoclastic/mixed sediments are indicative of highly explosive volcanism. *Permian*
Kolínovce, Spišsko-gemerské rudohorie Mts.
The uppermost part of Petrova Hora Fm. With claystones, siltstones and local layers of redeposited volcanoclastics. Parallel-layered thin patches of sandstones of low-energy streamflows, which existed immediately in front of the alluvial fan. Assymetric wave ripples are exposed. *Permian*
Ostrá skalka, Rákoš, Spišsko - gemerské rudohorie Mts.
Basal part of Gočaltovo Group, Rožňava Fm., Southern Gemericum. Thick bedded oligomict conglomerates with low textural maturity indicating alluvial water deposits, mostly stream-channel and sheet-flood deposits of typical verrucano facies. *Permian*
Road Gočaltovo-Štítnik, Spišsko-gemerské rudohorie Mts.
Štítnik Fm. - upper part of Gočaltovo Fm. - Lagoonal sediments - a complex of well stratified sandy-dolomitic limestones with intercalations of light green-grey shales. *Upper Permian* to *Lower Triassic*
Večný dážď („Eternal rain„), Velická valley, Vysoké Tatry Mts.
Megaxenolite of the metamorphites in the neighbouring granites
Velická dolina, Vysoké Tatry, an outcrop in the path to the Dlhé pleso tarn
Magmatic contact of two types of granitoids and diorite enclaves in granitoids.
Žiarska dolina, Západné Tatry Mts.,
Natural outcrop of banded amphibolites on a contact of the Hercynian nappe structure.
Vyšné Matejkovo, Podsuchá, Veľká Fatra Mts., quarry
Etalon of the Smrekovica tonalite (complete geochemical - isotopic characteristics).
Kolbašský jarok (Kolbachy creek), Branisko Mts.
"Pseudopillow" structures in gabro in the anatexy and migmatites zone

Rösslerov lom quarry, Bratislava, Malé Karpaty Mts.
Granite pegmatite body with more than 60 mineral forms

Klenovský Vepor, Veporské vrchy Mts., natural outcrops
Cliffs of porphyric granodiorites with subhorizontal foliations. Granitoid body creates a substratum for Tertiary volcanic rocks. *Permian*

Hriňová, Veporské vrchy Mts., natural outcrops
Basal diorite enclaves in the Sihla type granodiorite with indications for mixing of two magmas, 300 Ma.

Muráň, Spišsko-gemerský kras Mts., natural outcrop-Contact of crystalline and Mesozoic rocks of the Muráň nappe unit, exposed along an important Muráň fault

MESOZOIC

Belianska dolina valley, Veľká Fatra Mts.,
Lithostratigraphic profile through the Tatricum envelope sequence, *Triassic - Cretaceous*

Orava castle rock massif, Oravský Podzámok
Lithostratigraphic profile through the Klippen belt, *Jurassic*

Ždiar, Vysoké Tatry Mts., road-cut
Lithostratigraphic profile of the Carpathian Keuper of the Krížna nappe, *Norian*

Podtureň, Nízke Tatry Mts., quarry
lithostratigraphic profile of the Lunz beds of the Choč nappe, *Carnian*

Skladaná skala, Chočské vrchy Mts., quarry
Type locality of the Allgäu beds (Fleckenmergel), lithological profile, Križná nappe, *Lotharingian*

Doggerské skaly (Doggerian rocks), Trlenská dolina valley, Veľká Fatra Mts., protected area – Natural Monument, type locality of the Ždiar Fm., radiolarian limestones, radiolarites, Križná nappe, *Upper Bathonian - Oxfordian*

Veľký and Malý Rozsutec Hills, **Jánošíkove diery**, Vrátna dolina valley, Malá Fatra Mts.,
Demonstration of nappe structures of the Western Carpathians - contact between the Krížna and the Choč nappes

Meliata, Slovenský kras Mts., creek-bluff
Type locality of the Meliata Unit and Meliata Fm., *Jurassic* with *Triassic* olistholits

Hačava and Šugov valleys, Slovenský kras Mts., creek-bluff
Subduction-accretionary complex of the *Triassic-Jurassic* Meliatic ocean with exhumed blue-schists Complexes. Rarity: carbonate platform with volcanites (glaucophanites), Bôrka nappe.

Haligovce, Pieniny Mts., natural outcrop
Stratigraphy profile through the Haligovce unit of the Klippen belt (carbonates/flysch/marls), *Triassic–Paleocene*

Dlhá n. Oravou – Dlhánsky Cickov, Oravská Magura Mts., abandoned quarry
Sandstones, tectonic slice of the Magura unit in the Klippen belt, *Eocenian*

PALEOGENE

Sološnica, Malé Karpaty Mts.,
Transgression of the Paleogene sediments on the karstified Triassic limestone, large foraminifers, *Middle Eocenian*

Ráztočno, Handlová basin, quarry
Elipsoidal fragmentation of the weakly cemented conglomerates and sandstones of the Biely potok Fm., *Oligocene-Miocene (Egerian)*

Lisková, Liptovská kotlina basin
Large foraminifers and macrofauna in the Borovská Fm., *Upper Lutetian*

Radôstka, Kysucká vrchovina upland, road cut
P-stratotype of the flysch Bystrica beds (alternation of sandstones and claystones), Magura unit, *Eocenian*

Radôstka, Kysucká vrchovina upland, creek bed
P-stratotype of the flysch Beloveža beds (alternation of sandstones and claystones), Magura unit, *Eocenian*

Ružomberok, quarry
Transgression of the Borovská Fm. – conglomerates on *Triassic* dolomites, *Priabonian*

Ružomberok, brickfield, pit in operation
Claystones - Hutianska Fm., *Priabonian*

Kňažia, Orava, roadcut
Transgression of the Borovská Fm. on the Klippen belt, *Upper Lutetian*

Pucov, Orava, roadcut, protected area – Natural Monument
Stratotype of the Pucov conglomerates, submarine slump body, *Lower Priabonian*

Oravský Biely Potok, Orava, abandoned quarry
Stratotype of the Biely Potok Fm. (sandstones), *Lower Oligocene*

Kežmarok, Popradská kotlina basin, abandoned quarry
Stratotype locality of the Kežmarok beds, *Oligocene*

Korňa, Turzovská vrchovina upland
Oil-field water spring, Zlín Fm., flysch Magura unit, *Eocenian*

Krásno n. Kysucou, Kysucká vrchovina upland, road cut
Stratotype locality of the Kýčera beds (alternation of sandstones and claystones)
flysch Magura unit, *Eocenian*

Stará Lesná, Poprad basin, creek bluff
Flysch of the Zuberec Fm, *Eocenian*

Terchová – Berešíci, Kysucká vrchovina upland, natural outcrop
Olistostrome body in flysch sequence of the Klippen belt *Paleogene, Eocenian*

Ždiar, Poprad basin, roadcut
Chaotic conglomerates with intraclasts of the Pucov beds, *Priabonian*

Svetlice, Laborecká vrchovina upland, natural outcrops along creek
Stratigraphy profile through flysch sequences of the Dukla unit, *Paleocene - Oligocene*

Spišské Tomášovce, Hornád basin, quarry in operation
Stratotype of the Tomášovce beds, sandstones, siltstones, macrofauna Pectens, *Priabonian*

Záblatie, Javorníky Mts., creek bluff
P-stratotype of the flysch of the Magura unit (alternation of sandstones and claystones), *Senonian*

NEOGENE - VOLCANICS

Burda - Kamenica nad Hronom, Burda Mts., abandoned quarry, protected area

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Submarine andesite volcanics - hornblende-hypersthene andesite extrusive dome and related hyaloclastite breccias, breccia flow deposits, reworked phreatomagmatic pyroclastic rocks and conglomerates, *Early Badenian*

Stará Huta – Blýskavica,
Type section of the Blýskavica Fm., basaltic andesite lava flows and related hyaloclastite breccias, *Early/Middle Badenian*

Hrochoť - Jánošíkova skala, Žiarec, Poľana Mts., natural cliffs, Natural Monument
Type section in the proximal zone of the Abčina and Veľká Detva Fms, alternating pyroxene and hornblende-pyroxene andesite epiclastic volcanic breccias, reworked pyroclastic breccias, rare pyroclastic flow deposits and lava flows, capped by pyroxene andesite lava flows of the Veľká Detva Fm., *Sarmatian*

Medovarce, natural cliffs
Typical section in the distal zone of the Sebechleby Fm., alternating pyroxene and hornblende-pyroxene andesite mudflow deposits with conglomerates and sandstones of coastal zone, *Badenian*

Plášťovce, natural cliffs and outcrops
Type section in the distal zone of the Sebechleby Fm./ Plášťovce Member, fauna bearing tuffaceous siltstones with conglomerate/sandstone slump and density current bodies filling erosion channels, *Badenian*

Hronská Breznica, Banská Štiavnica Mts., natural cliffs and outcrops, Natural Monument
Type section of the Breznica Complex, - crosscut of a large fan at the northern side of the Štiavnica stratovolcano made up by alternating andesite mudflow, debris flow and hyperconcentrated flow deposits (epiclastic breccias), pyroclastic flow deposits and lava flows, *Early/Middle Sarmatian*

Banská Štiavnica – Glanzenberg, Banská Štiavnica Mts., Natural Monument
Outcrops of the Spitaler base metal epithermal vein with remnants of Middle age mining works. Cliffs above the medieval mining city Banská Štiavnica (on the UNESCO List of Cultural Heritage).

Hliník nad Hronom - Szabova skala, Banská Štiavnica Mts., Natural Monument
Type locality of the Jastrabá Fm., rhyolite extrusive dome with well preserved glassy margin and related hyaloclastite breccias, *Late Sarmatian*

Remata - Bralová skala, Kremnické vrchy Mts., natural cliffs, Natural Monument
Type locality in the proximal zone of the Remata Fm., alternating pyroxene andesite lava flows, epiclastic breccias, capping pyroclastic flow deposits, *Early/Middle Sarmatian*

Žiar nad Hronom - Šibeničný vrch Mt., Kremnické vrchy Mts., abandoned quarry
Type locality of the Šibeničný vrch Complex, *Pannonian age* - high alumina basalt dyke cutting *Late Sarmatian* conglomerates and remnants of a related tuff cone - phreatomagmatic surge and fall palagonite tuffs with numerous bombs.

Nevoľné, Kremnické vrchy Mts., large road cuts
Type locality of the Kremnický štít Fm., thick hornblende-pyroxene andesite lava flows with characteristic platty jointing at the base and coarse blocky breccias at the top, *Late Badenian*

Ihráč, Kremnické vrchy Mts., natural outcrops
Typical locality of the Krahule Fm., biotite-hornblende andesite dome flow with related hyaloclastite breccias at the base, oxidised block-lava breccias at the top, *Late Badenian*

Kamenec pod Vtáčnikom, Vtáčnik Mts., natural outcrops
Type section of the Kamenec Fm. - conglomerates and sandstones overlain by remnants of the coal-bearing Nováky Fm., *Early Badenian*

Pokoradza, Cerová upland, abandoned quarries and natural cliffs
Type section of the Pokoradz Fm., - basal shallow marine sandstones are overlain by mudflow (lahar) deposit, fine to coarse conglomerates and capping pyroclastic flow deposits. Features of large scale sliding on underlying *Early Miocene* sediments, *Badenian*

Šurica - Soví hrad, Cerová upland, natural cliff – Natural Monument
Type locality of the Cerová Basalt Fm. – alkali-olivine basalt diatreme with palagonite tuff/scoria filling. Processes of diatreme formation documented by textures, *Pliocene*

Rankovce - Rankovské skaly (Ranková rocks), natural cliffs
Type section in the central zone of the Rankovce Fm. (volcano) - remnants of volcanic cone made up by aternating thin and highly brecciated pyroxene andesite lava flows, pyroclastic breccias, agglomerates and tuffs, *Sarmatian*

Dubník – opal mines, Slánske vrchy Mts., Natural Monument
Abandoned medieval precious opal mines.

NEOGENE - SEDIMENTARY

Bretka, South-Slovakian basin, abandoned quarry
Correlation hypostratotype for Central Paratethys and facies-stratotype of transgressive conglomerate and limestone Fm., *Egerian*

Podbranč, Vienna basin, quarries partly in operation
Slovak facies-stratotype of the littoral conglomerate-sandstone development, transgressive position over Klippen belt, *Eggenburgian*

Cerová-Lieskové, Vienna basin, loam pit
Type profile of the off-shore aleuropelites with rich index fauna, *Karpatian*

Sandberg, Devínska Nová Ves, Vienna basin, abandoned sand pit, Natural Monument
Littoral facies-stratotype of the *Upper Badenian* sediments

Pezinok, Danube basin, loam pit, partly in operation
Correlation locality of the *Pannonian* clayey sediments of the Ivánka Fm.

Košice, East-Slovakian Neogene Basin, pit
Stretava Fm., deltaic and shallow marine clastics, *Sarmatian*
Košická Polianka, East Slovakian Neogene basin, pit-Stretava Fm., beach and shoreface deposits, *Sarmatian*
Varhaňovce, East Slovakian Neogene Basin, pit
Klčovo Fm., Gilbert type deltaic deposits. *Late Badenian*

QUATERNARY

Močarany, East Slovakian Neogene Basin, pit
Loess-like loams and fossil soils, *Holsteinian, Saalian*
Gánovce, Poprad basin, abandoned quarry, Natural Monument
Travertines, in which the cast of a brain of the *Homo neanderthalensis* was found (120.000 years old).
Dreveník, Spišské Podhradie, Spiš castle, Žehra, Hornádska kotlina basin, National Natural Monument
Unique gravitational disintegration of Dreveník travertine mound by creep movements. The part of Dreveník – Spiš castle – is a constituent of the World Cultural Heritage.
Chabenec Mt., Nízke Tatry Mts., Nízke Tatry Mts. National Park
Rock slide – an impressive feature of a deep-seated gravitational deformation.
Tatranská Polianka - (Veľká žltá stena), Vysoké Tatry Mts., natural outcrop
Profile of periglacial polygenetic accumulations, *Middle/ Late Pleistocene*
Nová Lesná, Studený Potok valley, Vysoké Tatry Mts., natural outcrop
Stratotype locality of Nová Lesná beds - glacifluvial sands, *(? Biber)*
Vavrišovo, Belá valley, Vysoké Tatry Mts., gravel pit
Stratotype locality of Vavrišovo beds - glacifluvial gravels and sands (*Mindel*)
Nová Baňa - Brehy, Hron valley, Štiavnické vrchy Mts., quarry
The youngest volcano in Slovakia (180.000 years) with basalt lava flow on *Middle Pleistocene* fluvial gravels of the Hron terrace, covered by fossil soil of the latest Interglacial
Veľký Kýr (Milanovce), Nitra valley, Nitrianska pahorkatina hilly land, road cut
Fossil soil complex (red clays – red soils), *Lower Pleistocene*
Lukáčovce, Nitrianska pahorkatina hilly land, sand pit
Stratotype locality of the Lukáčová beds - fluviolimnic sandy gravels, *Lower Pleistocene*
Komjatice, Nitrianska pahorkatina hilly land, brickfield pit
Loess and fossil soils complex with occurrence of volcanic ash, *Middle Pleistocene*
Mnešice, Váh valley, Trnavská pahorkatina hilly land, brickfield pit
Loess and fossil soils complex, *Middle/Late Pleistocene*
Senec, Trnavská pahorkatina hilly land,
Loess and fossil soils complex, *Pleistocene*
Hajnáčka, Cerová vrchovina upland, erosion gully
Maar sediments with *Vertebrata* fauna, *Late Pliocene*
Ratka, Cerová vrchovina upland, quarry
Fluvial sediments with superincumbent basalt lava flow and fossil soils, *Lower Pleistocene*
Husina, Lučenská kotlina basin, quarry
Fluvial sediments *(Lower Pleistocene)* with superincumbent basalt lava flow, loess and fossil soils complex *(Middle/Late Pleistocene)*
Hranovnica, Nízke Tatry Mts., natural outcrop
Travertines, *Late Pliocene/Lower-Middle Pleistocene*
Sivá Brada, Spišské Podhradie, Hornádska kotlina basin
A travertine mould, present travertine deposition, *Late Pleistocene/Holocene*
Caves of the Slovenský kras Mts., 3 caves o f the Slovenský Kras and Aggtelek kras karst - on the UNESCO list of the World Cultural and Natural Heritage
Demänová cave, Demänová valley, Nízke Tatry Mts., National Natural Monument
The largest Slovak cave with the total length of more than 36 km

Literature

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Important note: Due a mistake in press two contributors of the above paper were omitted: Janočko, J., Lexa, J.

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