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The journal is focused on problems of the Alpine-Carpathian region.

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Timing of the Ditrau alkaline intrusive complex (Eastern Carpathians, Romania)

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Abstract. On the basis of K-Ar and $^{39}Ar/^{40}Ar$ data, the following timing is suggested for the emplacement of the Ditrau Alkaline Intrusive Complex:

1) During Carnian (c.230 Ma), in the Middle-Triassic extensional stage a mantle derived gabbro-dioritic magma with mantle xenoliths was emplaced.

2) During Norian time (c.215 Ma) this gabbro-dioritic mass rose into the crust in a subsolidus stage and penetrated a crustal syenitic magma. Under these dynamic conditions, magma mingling and magma mixing occurred and a large variety of hybrid rocks formed.

3) During the Callovian-Oxfordian (c.160 Ma), in the Middle-Jurassic rifting (Civcin-Severin rift and spreading system), a mantle derived nepheline syenite magma that formed by partial melting intruded the Triassic Ditrau massif and veined all previously formed rocks. Mafic foid-rocks (ditro-essexite) formed by hybridization and partial metasomatic substitution. After this event, cooling below 300 °C lasted for 20-25 Ma, until the Berriasian stage (c.135 Ma). It was followed until 115 Ma by local hydrothermal alteration and mineralization.

4) During Aptian (c.115 Ma) the definitive closing of the Ar system is explained by tectonic uplift due to nappe transport.

Key words: Eastern Carpathians, Ditrau Massif, K-Ar and Ar-Ar data

Introduction

The Ditrau Alkaline Intrusive Complex (DAIC) occurs in the Romanian East Carpathians, near Gheorgheni, Lazarea and Ditrau. It cuts the Pre-Alpine metamorphic rocks of the Bucovinian nappe near the Neogene-Quaternary volcanic arc of the Harghita-Calimani Mts. Andesitic pyroclastics and basalt-andesite lava flows from these volcanoes unconformably overlay parts of the DAIC. The Ditrau massif is also covered by sedimentary lacustrine deposits which separated the volcanic arc from the East Carpathian land mass during Upper Pliocene and Pleistocene (Fig.1).

Pre-Alpine metamorphic rocks of the Bucovinian Nappe (uppermost Alpine unit including metamorphics) occur over a large area surrounding the DAIC. These metamorphics were involved in several nappe structures that are cut by the DAIC and were welded by its thermal contact aureole (Fig.2). Since the first radiometric data suggested a Jurassic emplacement (Bagdasarian, 1972; Streckeisen and Hunziker, 1974) the Ditrau massif was considered to be a stitching intrusion that proves Variscan staking of the aforementioned nappe structure in the metamorphic basement of Alpine nappes (Balintoni, 1981; Muresan, 1983).

The DAIC is characterized by a peculiar lithologic constitution and complicated internal framework. The petrographic complexity involves large series of ultrabasic to acid silica- versaturated and silica-undersaturated alkaline rocks of both, massive and oriented textures. Various concepts and petrologic models were advanced in the course of time, ranging from metasomatic to magmatic origin and from emplacement by a single magmatic intrusion, to multiple successive intrusions (for details see Streckeisen, 1952, Codarcea et al., 1958, Pál-Molnár, 1994, Kräutner and Bindea, 1995).

In this contribution a three stage model (Kräutner and Bindea, 1995) based on radiometric data is used to date DAIC emplacement. The proposed model is supported by relationships between the main rock and mineral associations observed in the field and under the microscope. It assumes that (Figs.3, 4):

1. Earliest DAIC components are gabbros and diorites of mantle origin, with xenoliths of olivine pyroxenites, partly or completely altered into hornblendites.

2. During their rise into the crust, these rocks (probably in a subsolidus stage) were partly mixed and mingled with a crustal syenitic magma. In this dynamic environment a part of the syenitic magma evolved towards:

- flow-oriented monzonitic components by mixing with the ascending basic rocks
- granitic melts by assimilation of quartz rich crustal rocks.

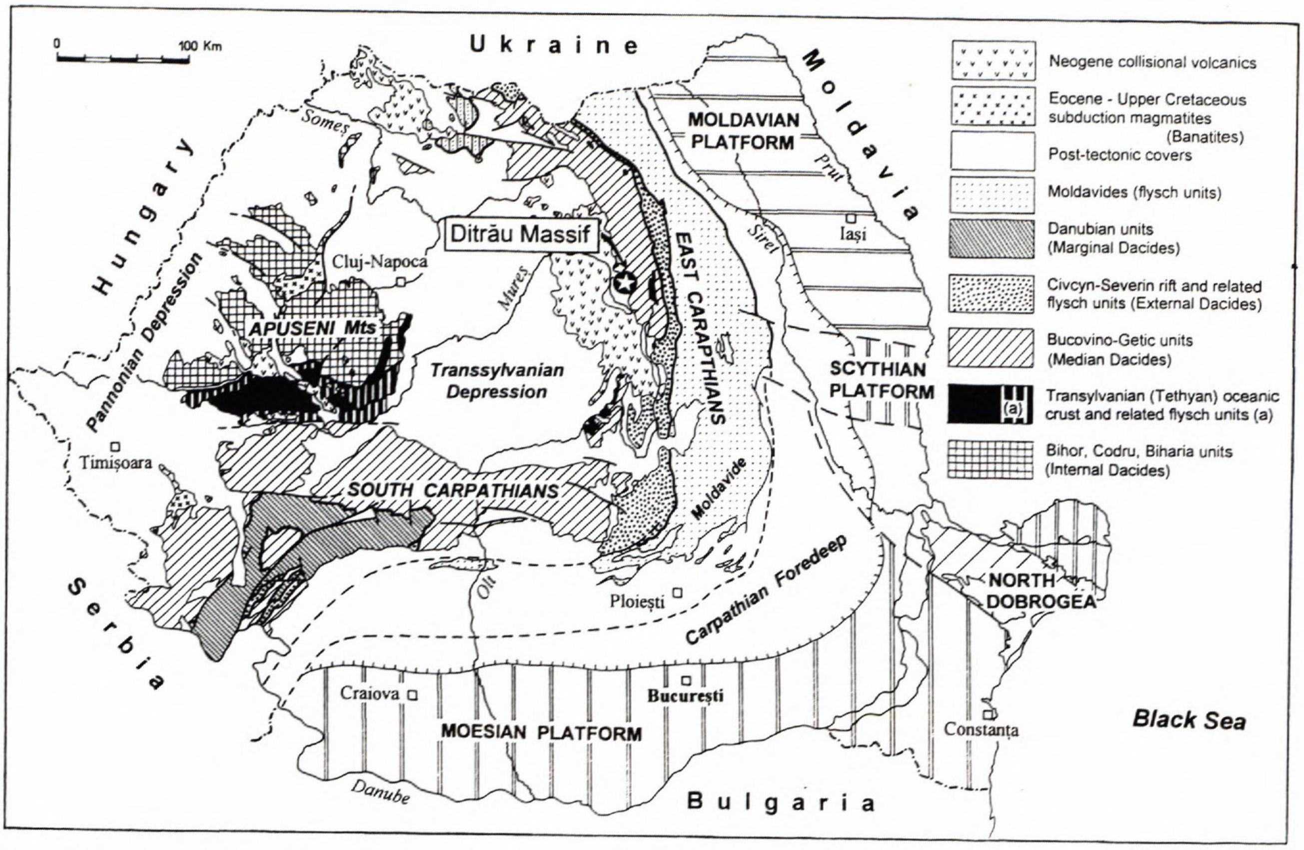

Fig.1 Position of the Ditrau Alkaline Intrusive Complex in the structural framework of the Romanian Eastern Carpathians.

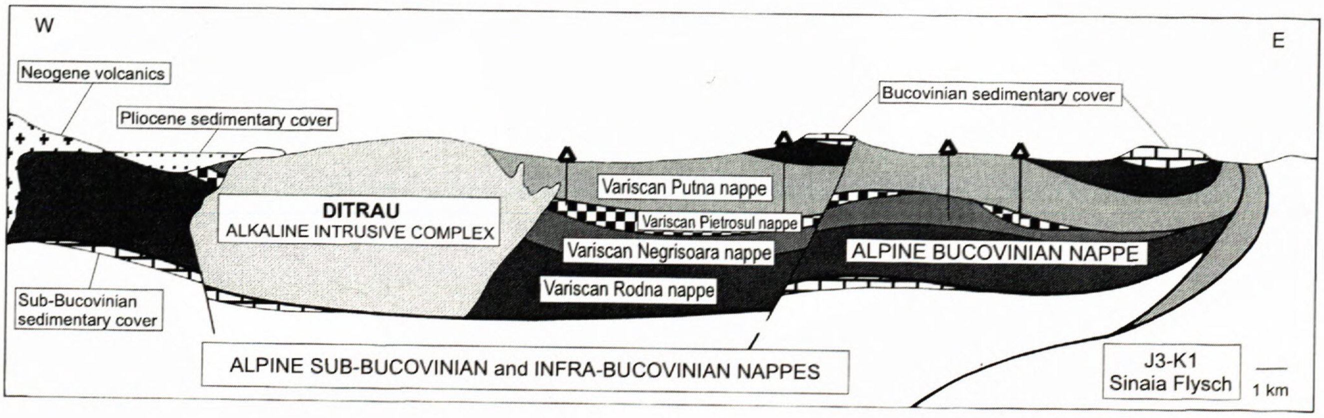

Fig.2 The Ditrau Massif is included in the Alpine Bucovinian nappe and cuts therein the Variscan nappe structure (Schematic geological profile through the Central Eastern Carpathians).

3. During a later stage a nepheline syenitic magma originated in the mantle by partial melting, intruded the aforementioned Ditrau rock associations. It produced in the previous DAIC rocks veining, hybridization and metasomatic alteration.

- In a late stage pegmatitic facies developed locally and sodalite and/or cancrinite bearing nepheline syenites formed
- tinguaite veins cut the whole structure
- a final hydrothermal stage associated with stockwork and vein mineralization concluded the development of the Ditrau complex,

4. During the first Alpine compressional stage the DAIC was involved in the Middle Cretaceous nappe system and was uplifted by tectonic transport.

Previous investigations

Various ages for the Ditrau Alkaline Intrusive Complex were assumed or inferred in early works ranging from Neogene to Paleozoic. Geologic relationships clearly show that the DAIC is younger than the surrounding Pre-Alpine metamorphic rocks and is considerably older than the Pliocene sedimentary cover.

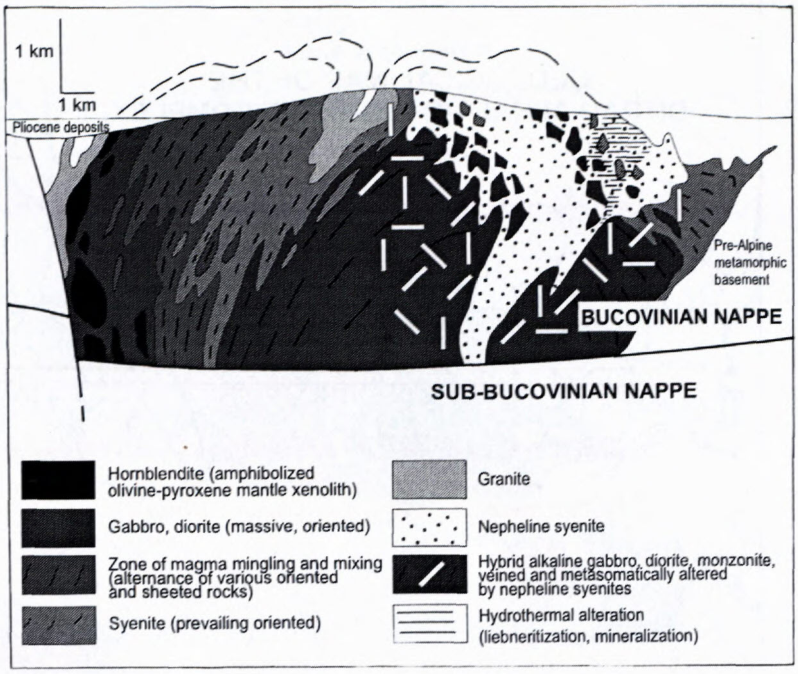

Fig. 3 Petrologic model for the internal structure of the Ditrau Alkaline Intrusive Complex.

Thus, a Mesozoic or younger age was considered by Mauritz and Vendl (1923) and a Post-Neocomian age was suggested by Reinhard (1911) and Földvári (1946), assuming genetic relations to the Neogene volcanics of the East Carpathians. Streckeisen (1931) suggested an intrusion in the Upper Cretaceous, while Ianovici (1938) envisaged a Jurassic age, because Liassic alkaline igneous rocks occur in the Brasov area. A Variscan emplacement was assumed by Pb-a ages of 297 Ma on zircon and 326 Ma on monazite (Ionescu et al., 1966).

Reliable estimates of the DAIC age appeared only since the first *K-Ar ages* were recorded. Bagdasarian (1972) suggested a Pre-Jurassic age (196 Ma) for hornblenditic rocks and an Upper Jurassic-Neocomian emplacement (140-120 Ma) of syenites and granites. More reliably, the nepheline syenites, tinguaites and the contact aureole were dated by Streckeisen and Hunziker (1974) at 160 Ma, with cooling below 300°C at 150 Ma. Between 1972-1981 Mînzatu et al. (1980,1981) recorded further K-Ar mineral and whole-rock ages ranging from 200 to 120 Ma. Based on isochron interpretations of the available K-Ar data, Kräutner et al. (1976) proposed an emplacement at 135 Ma and suggested cooling ages for the lower age values (122-115 Ma) and inherited Ar in rocks with higher age values (189-156 Ma). An *$^{40}Ar/^{36}Ar$-$^{40}K/^{36}Ar$ mineral isochrone* of 138.7±3 Ma for different DAIC biotites was also interpreted to indicate the closing age of the system (Mînzatu et al. (1981). A multistage evolution of the DAIC was proved by K-Ar dating since reliable Triassic K-Ar ages of 237-216 Ma (Pál-Molnár and Árva-Sós, 1995) and ^{40}Ar-^{39}Ar mineral plateau ages of 231-227 Ma (Dallmeyer et al., 1997) were recorded on hornblenditic and gabbroic rocks. A two stage model proposed by Pál-Molnár and Árva-Sós (1995) suggests a Middle Triassic-Lower Jurassic intrusion of hornblendites, nepheline syenites and granites, and a Middle Jurassic- Lower Cretaceous event that produced syenites, alkali-feldspar syenites and hybrid diorites.

Based on the first *Rb-Sr whole rock ages* Popescu (1985) inferred an ultrabasic intrusion at 200 Ma, followed by a syenite intrusion at about 160 Ma. A reinterpretation of these data and earlier K-Ar ages by Zincenco (1991) suggested the entering of the DAIC in the subsolidus stage at 171±3 Ma, ending of the pneumatolitic stage at 165±5 Ma and closing of the hydrothermal phase below 300°C at 154 Ma. Further Rb-Sr whole rock isochrone data were interpreted by Zincenco et al. (1994) in favour of a DAIC emplacement at 201±1 Ma, most probably in the Sinemurian. Based on a supplementary Rb-Sr isochrone of 231 Ma for ultrabasic rocks, Zincenco (1996, fide Postolache, 1997) suggested another age model involving the DAIC emplacement 231Ma ago, with the cooling of the marginal zones below 350°C at 201 Ma and the persistence of a central zone in a solid-liquid-gas stage until 123 Ma, when it pierced the solid cover zone. The system cooled below the hydrothermal stage at 116 Ma.

Interpretation of analytical data

K-Ar total gas ages and ^{40}Ar/^{39}Ar mineral plateau ages (Tables 1,2,3) recorded on Ditrau rocks in the course of time by different authors (Bagdasarian, 1972 were used to date the DAIC emplacement; Streckeisen and Hunziker, 1974; Mînzatu et al., 1980, 1981; Pál-Molnár and Árva-Sós, 1995; Dallmeyer et al., 1997). For stratigraphic time-scale the calibration of Gradstein et al. (1994) was used.

A rough statistic evaluation of all these data by histograms (Fig.5) indicates that age values cluster near two maximum domains, in which five secondary frequency peaks can be recognized at: ~235 Ma for hornblendite and gabbro-diorite ages; ~215 Ma for added granite ages, ~155 Ma, ~135 Ma and ~115 Ma for nepheline syenites and various pre-nepheline syenite rocks. This figure is compatible with our proposed petrogenetic model. It suggests (1) a Middle Triassic emplacement (~235 Ma) of gabbro-diorites with amphibolized mantle xenoliths, (2) followed in the Upper Triassic (~215) Ma by the crustal granitoids. (3) The nepheline syenite event appeared at the beginning of the Upper Jurassic (~160 Ma). It produced partial resetting of the Ar system in previously formed rocks. The continuously decreasing frequency of the age clusters at ~135 Ma and ~115 Ma, suggests a slow and long lasting cooling. During this period the late hydrothermal metasomatic activity and mineralization may bave taken place. Cessation of Ar loss at ~115 Ma fits well the suggested tectonic uplift by Alpine nappe transport during the Middle Cretaceous.

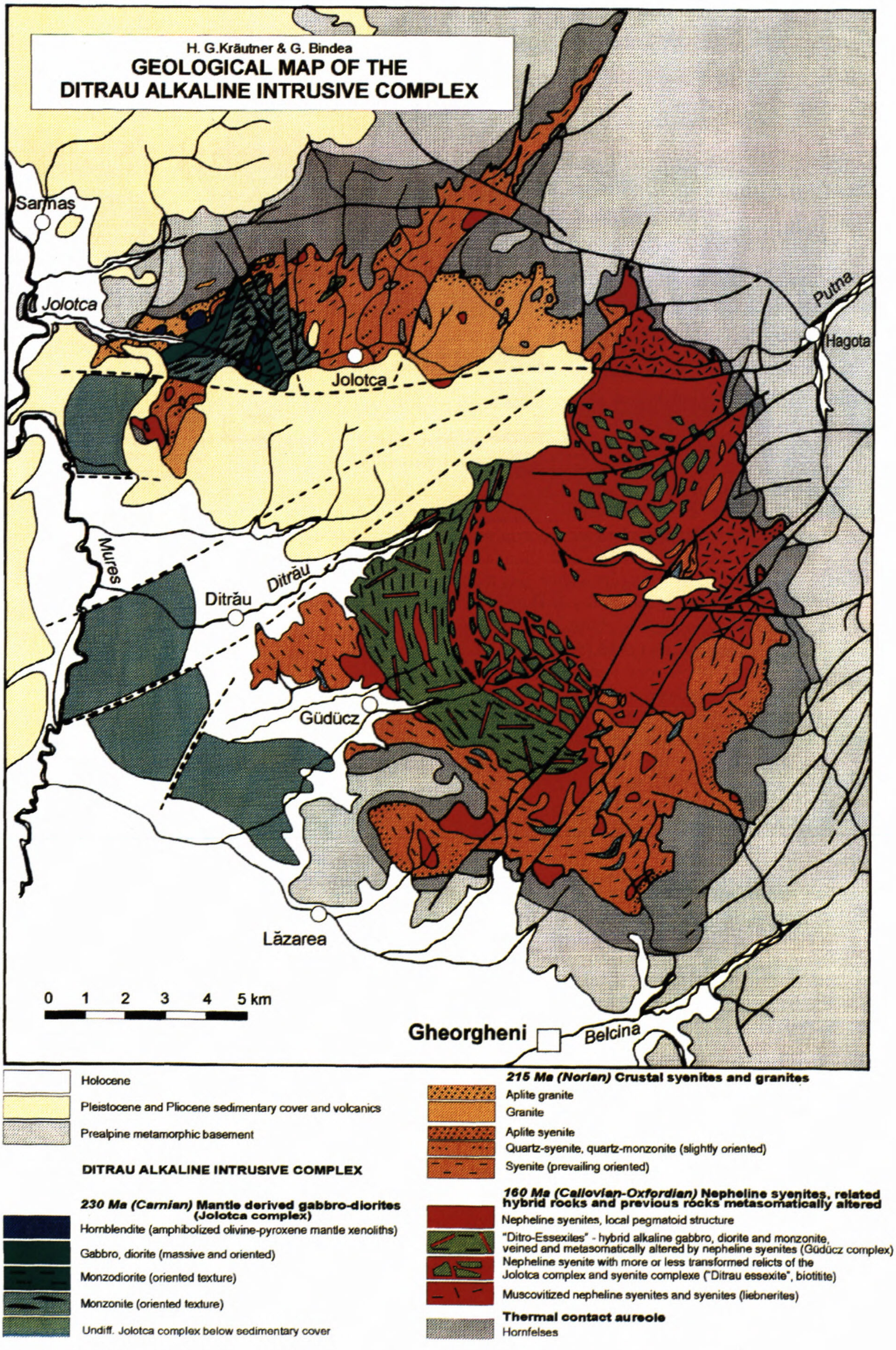

Fig.4 Geological map of the Ditrau Alkaline Intrusive Complex.

Table 2. *K-Ar ages of SYENITES and GRANITES from the Ditrau Alkaline Intrusive Complex recorded by Bagdasarian (1972), Ninzatu et al. (1980, 1981), Pál-Molnár and Árva-Sós (1995)*

Rock type	Locality	K-Ar total gas age				Sample	Source
		Biotite	**Muscovite**	**K-feldspar**	**Whole-rock**	Nr.	
Syenites (n=15)							
Syenite pegmatite	Hereb Valley, gallery 6		161,8±6,1			20	Mînzatu et al. (1981)
Pegmatoidic syenite (vein in hornbl.)	E confluence Teascului/Jolotca				143,5±0,5*(142±7)*	5137	Bagdasarian (1972)
Biotite-syenite (with titanite)	Ditrau-Tulghes road, km 11	139,3±5,1			136	2	Mînzatu et al. (1981, 1980)
Biotite-syenite	Ditrau Valley	134,3±4,8			131	3	Mînzatu et al. (1981, 1980)
Syenite	E confluence Simo/Jolotca				125,5±3*(128±3)*	5135	Bagdasarian (1972)
Syenite (folieted, vein)	Ditrau-Tulghes road				118±1*(121,5±0,5)*	5140	Bagdasarian (1972)
Biotite-syenite	Ditrau Valley	117			112		Mînzatu et al. (1980)
Biotite-syenite	Ditrau Valley, quarry	113,6±4,6				4	Mînzatu et al. (1981)
Syenite	Teascului Valley, gallery 19	107,6±4,1		182,7±6,9		6680	Pál-Molnar & Árva-Sós (1995)
Alkali feldspar syenite	Simo Valley	102,6±4,0		113,5±4,3		6679	Pál-Molnar & Árva-Sós (1995)
Granites, aplite granites (n=8)							
Granite	Török Valley	217,6±8,3		146,0±5,6		6677	Pál-Molnar & Árva-Sós (1995)
Granite	Teascului Valley	213,5±8,2		139,1±5,4		6703	Pál-Molnar & Árva-Sós (1995)
Granite	Naghag Valley	206,3±7,8		142,7±5,7		6704	Pál-Molnar & Árva-Sós (1995)
Aplite	Borehole 120, m 2				141,9±5,5	19	Mînzatu et al. (1981)
Leucogranite	Confluence Hompot/Jolotca				121,2±12*(125±10)*	5133	Bagdasarian (1972)

Calculated with constants recommended by Steiger and Jäger (1977), values from Bagdasarian (1972) recalculated by Zincenco et al. (1994) with constants recommended by Jäger and Steiger (1975); original published values in brackets

Table 1. *K-Ar and ^{40}Ar-^{39}Ar ages of HORNBLENDITES and GABBRO-DIORITES from the Ditrau Alkaline Intrusive Complex*
recorded by Bagdasarian (1972), Ninzatu et al. (1981), Pál-Molnár and Árva-Sós (1995), Dallmeyer et al. (1997)

Rock type	Locality	K-Ar total gas age				^{40}Ar-^{39}Ar plateau age	Sample	Source
		Hornbl.	**Biotite**	**Plagioclase**	**Whole-rock**	**Hornblende**	Nr.	
Hornblendites (n=13)								
Hornblendite	Tarnita Valley	237,4±9,1					6546	Pál-Molnar & Árva-Sós (1995)
Pegmatoidic hornblendite	Tarnita Valley	234,7±10,8	162,4±6,1	161,3±9,8			6705	Pál-Molnar & Árva-Sós (1995)
			168,3±7,2				6705	Pál-Molnar & Árva-Sós (1995)
Hornblendite	Jolotca Valley, gallery 6	226,0±9,6					6548	Pál-Molnar & Árva-Sós (1995)
Hornblendite	Pietrarilor Valley	216,0±8,8					6547	Pál-Molnar & Árva-Sós (1995)
Hornbl. lense in oriented diorite	Confluence Tasok/Jolotca				195±8 *(196±6)*		5138	Bagdasarian (1972)
Hornblendite with plagioclase incl.	Ditrau-Tulghes road				174±1*(177±1)*		5139	Bagdasarian (1972)
Hornblendite (xenolith)	W confluence Halasag/Jolotca				159±12*(161±10)*		5134a	Bagdasarian (1972)
Hornblendite in oriented syenite	W confluence Simo/Jolotca				156±2*(161±2)*		5136a	Bagdasarian (1972)
Biotitite (biotitized hornblendite)	Jolotca Valley		161,0±6.3				22	Mînzatu et al. (1981)
Biotite-hornblendite	Jolotca Valley		134,5±5,2				21	Mînzatu et al. (1981)
Gabbro-diorites (n=8)								
Hornbllende-diorite	Ditrau-Tulghes road, km 7					231,5±0,1	2	Dallmeyer et al. (1997)
Gabbro	Jolotca Valley					227,1±0.1	1	Dallmeyer et al. (1997)
Diorite with feldspar aggregates	Teascului Valley	218,7±8,3		255,4±5,8			5667	Pál-Molnar & Árva-Sós (1995)
Meladiorite	Teascului Valley	208,3±8,3		138,2±5,8			6549	Pál-Molnar & Árva-Sós (1995)
Diorite	Teascului Valley	176,6±6,7		137,4±5,5			6550	Pál-Molnar & Árva-Sós (1995)

Calculated with constants recommended by Steiger and Jäger (1977), values from Bagdasarian (1972) recalculated by Zincenco et al. (1994) with constants recommended by Jäger and Steiger (1975); original published values in brackets.

Table 3. *K-Ar ages of NEPHELINE SYENITES, TINGUAITES and HORNFELSES from the Ditrau Alkaline Intrusive Complex recorded by Bagdasarian (1972), Streckeisen and Hunziker (1974). Ninzatu et al. (1980, 1981), Pál-Molnár and Árva-Sós (1995)*

Rock type	Locality	K-Ar total gas age			Sample	Source
		Biotite	**Nepheline**	**Whole-rock**	Nr	
Nepheline syenites (n=5)						
Nepheline syenite	Ditrau Valley	156±3*(153±3)*			1764	Streckeisen & Hunziker (1974)
Nepheline syenite	Comarnic	154±9*(151±9)*			429	Streckeisen & Hunziker (1974)
Nepheline syenite	Ditrau Valley		150,9±5,8		7	Mînzatu et al. (1981)
Nepheline syenite	Ditrau-Tulghes road			147±2*(152±1)*	5142	Bagdasarian (1972)
Pegmatoidic nepheline syenite	Ditrau Valley, quarry		116,1±4,4		9	Mînzatu et al. (1981)
Metasomatically altered nepheline syenites and syenites (n=7)						
Nepheline syenite with sodalite	Teascului Valley	182,4±6,9	232,7±8,8		6678	Pál-Molnar & Árva-Sós (1995)
Nepheline syenite with cancrinite	Ditrau Valley		147,4±6,0		8	Mînzatu et al. (1981)
Nepheline syenite with cancrinite	Ditrau Valley	136,9±5,1			5	Mînzatu et al. (1981)
Biotite-syenite with cancrinite	Csanod Valley	126,0±5,0			6	Mînzatu et al. (1981)
Syenite with sodalite (vein)	Ditrau-Tulghes road, km 7	120,0±4,5			1	Mînzatu et al. (1981)
Liebneritized nepheline syenite	Ditrau Valley		81,3±3,1		10	Mînzatu et al. (1981)
Tinguaites (n=5)						
Tinguaite	Confluence Aurora/Belcina			172,0±6,6	16	Mînzatu et al. (1981)
Tinguaite	Pricske			164±7*(161±7)*	835	Streckeisen & Hunziker (1974)
Tinguaite	Aurora Valley			159,3±6,1	17	Mînzatu et al. (1981)
Tinguaite	Csanod Valley.			159±6*(156±6)*	204	Streckeisen & Hunziker (1974)
Tinguaite	Csanod Valley			141,9±5,5	18	Mînzatu et al. (1981)
Hornfelses (n=4)						
Biotite hornfels	Aurora Valley, gallery 7			172		Mînzatu et al. (1980)
Biotite hornfels	Teascului Valley	152±6*(150±6)*			1195	Streckeisen & Hunziker (1974)
Phlogopit marble	Lazarea, borehole 141, m 137	156,8±5,9			24	Mînzatu et al. (1981)
Biotite hornfels	Aurora, borehole 144			138		Mînzatu et al. (1980)

Calculated with constants recommended by Steiger and Jäger (1977), values from Bagdasarian (1972) and Streckeisen and Hunziker (1974) recalculated by Zincenco et al. (1994) with constants recommended by Jäger and Steiger (1975); original published values in brackets.

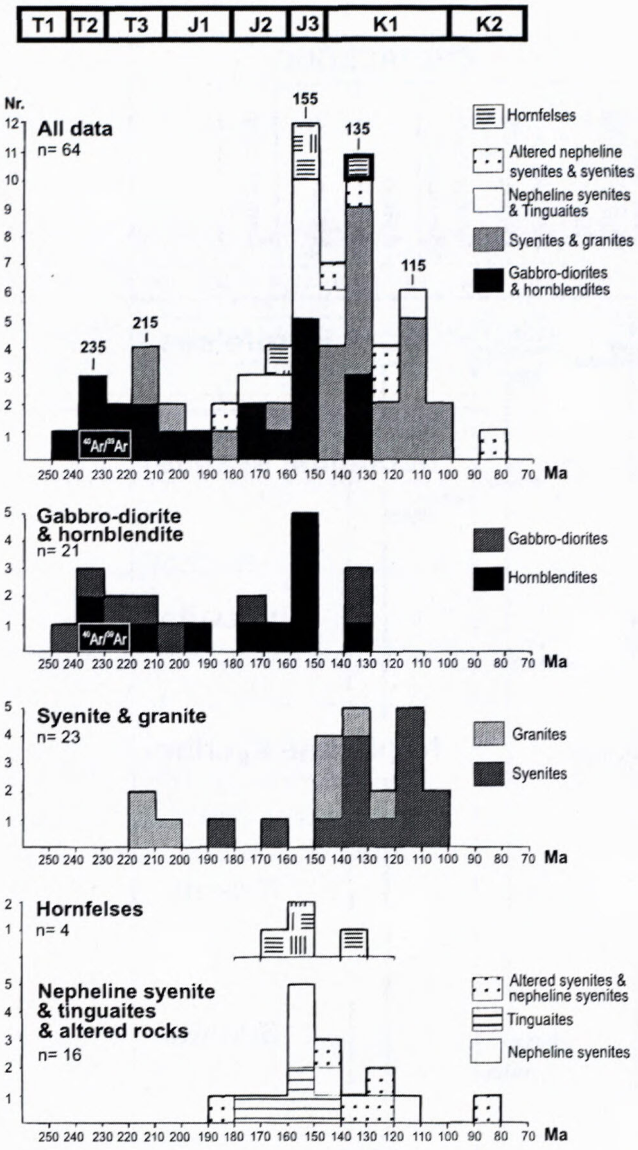

Fig. 5 Histograms with K-Ar total gas ages and $^{39}Ar/^{40}Ar$ mineral plateau ages from rocks of the Ditrau Alkaline Intrusive Complex. (Data from Bagdasarian, 1972; Streckeisen and Hunziker, 1974; Mînzatu et al., 1980,1981; Pál-Molnár and Árva-Sós, 1995; Dallmeyer et al., 1997)

A more detailed and reliable analysis, based on overlapping age intervals of error ranges (±) for individual samples (bars in Fig.6), suggests the following scenario:

(1) an early basic intrusion cooling below 500 °C between 231-227 Ma, as indicated by $^{40}Ar/^{39}Ar$ hornblende plateau ages from gabbro and diorite, as well as hornblende K-Ar total gas ages from hornblendite. Thus, conventionally, the *gabbro-diorite emplacement and accommodation of mantle xenoliths in these rocks occurred in the Carnian, at ~230 Ma,* as suggested by Dallmeyer et al. (1997). Recently, an age of 231 Ma was proposed by Zincenco (1996, fide Postoloache, 1997), on the basis of a Rb-Sr isochrone for ultrabasic rocks. Apparently, in hornblendites and gabbro-diorites argon systems of biotite-, plagioclase- and whole-rock were partly influenced by Jurassic heating, hybridization, metasomatic changes and recrystallization, produced by the penetrative nepheline syenite event. The rejuvenated biotite and feldspar K-Ar ages suggest tah the whole rock complex, a cooling below 300 °C between 160-140 Ma.

(2) For biotite from granites, an overlapping K-Ar age interval of 216-212 Ma may be considered, indicating cooling below 300 °C. Thus, conventionally, the *final emplacement stage of granitic- and associated syenitic granitoids can be assumed in Norian, at ~215 Ma.* A muscovite age of syenite-pegmatite suggests Jurassic partial heating over 400 °C at ~160 Ma, during the nepheline syenite event. A slow cooling of granites, syenites, gabbro-diorites and hornblendites down to 300 °C, until 135-130 Ma, is suggested by rejuvenated K-Ar ages of biotite from syenite and hornblendite, of feldspar from granites, gabbro-diorites and of whole-rock ages.

(3) The nepheline syenite emplacement was the last important thermal event in the DAIC, since the veining, hybridization and metasomatic influences nearly the whole massif. The best dating of this event may be inferred from tinguaite ages, as proposed by Streckeisen and Hunziker (1974). Tinguaites formed fast cooling veins in the final stage of the nepheline syenite intrusion. Overlapping whole-rock K-Ar ages of tinguaites are between 165-160 Ma. Biotite and nepheline ages of nepheline syenites cluster around 155 Ma. This age interval (165-155 Ma) complies with the aforementioned rejuvenated muscovite, biotite, feldspar and whole-rock K-Ar ages, recorded in syenites and hornblendites. Consequently the *emplacement of nepheline syenites may be inferred to be Callovian, with a possible extension into Lower Oxfordian, at 165-160 Ma.* In hornfelses, prevailing biotite ages mark this event.

(4) In metasomatically altered nepheline syenites, as well as in syenites, which are the most suitable rocks for the postmagmatic alteration, biotite-, feldspar- nepheline- and whole-rock ages cluster around 135 Ma and 115 Ma. We interpret the age of 135 Ma as a partial cooling below 300 °C and the end of high temperature metasomatic activity. The 115 Ma event probably marks the final stage of hydrothermal activity and definitive cooling due to tectonic uplift by nappe transport.

Proposed timing of the DAIC emplacement

Considering the above interpretation of analytical data and the proposed petrogenetic model the following timing is suggested for the DAIC emplacement (Fig.7):

c.230 Ma - Carnian *(231-227 Ma ^{40}Ar- ^{39}Ar Hornblende plateau ages and 235-225 Ma overlapping interval for K-Ar hornblende ages of gabbro and hornblendite).* On the South European passive continental margin a mantle derived gabbro-dioritic magma raised up due to mantle plume activity related to the Middle Triassic extensional stage (Dallmeyer et al., 1997). In the Bucovinian sedimentary cover this Middle Triassic extension is recorded by Ladinian radiolarites (Sandulescu, 1973) which cover the Anisian platform dolomites. The ascending magma contai-

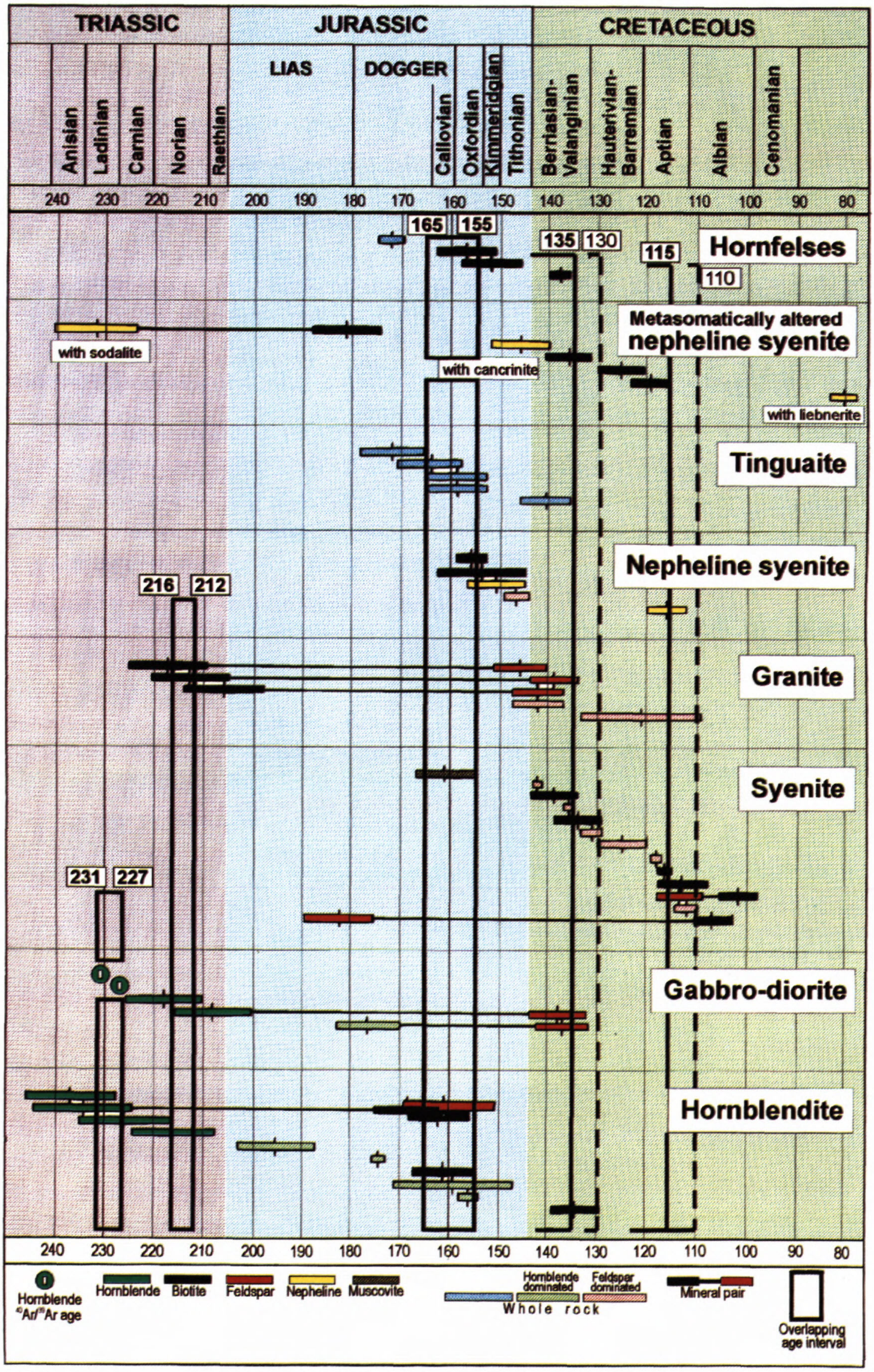

Fig.6 Overlapping intervals for error ranges of K-Ar total gas ages and $^{39}Ar/^{40}Ar$ mineral plateau ages from rocks of the Ditrau Alkaline Intrusive Complex. Bars indicate analyses with analytical error intervals. (Data from Bagdasarian, 1972; Streckeisen and Hunziker, 1974; Mînzatu et al., 1980,1981; Pál-Molnár and Árva-Sós, 1995; Dallmeyer et al., 1997)

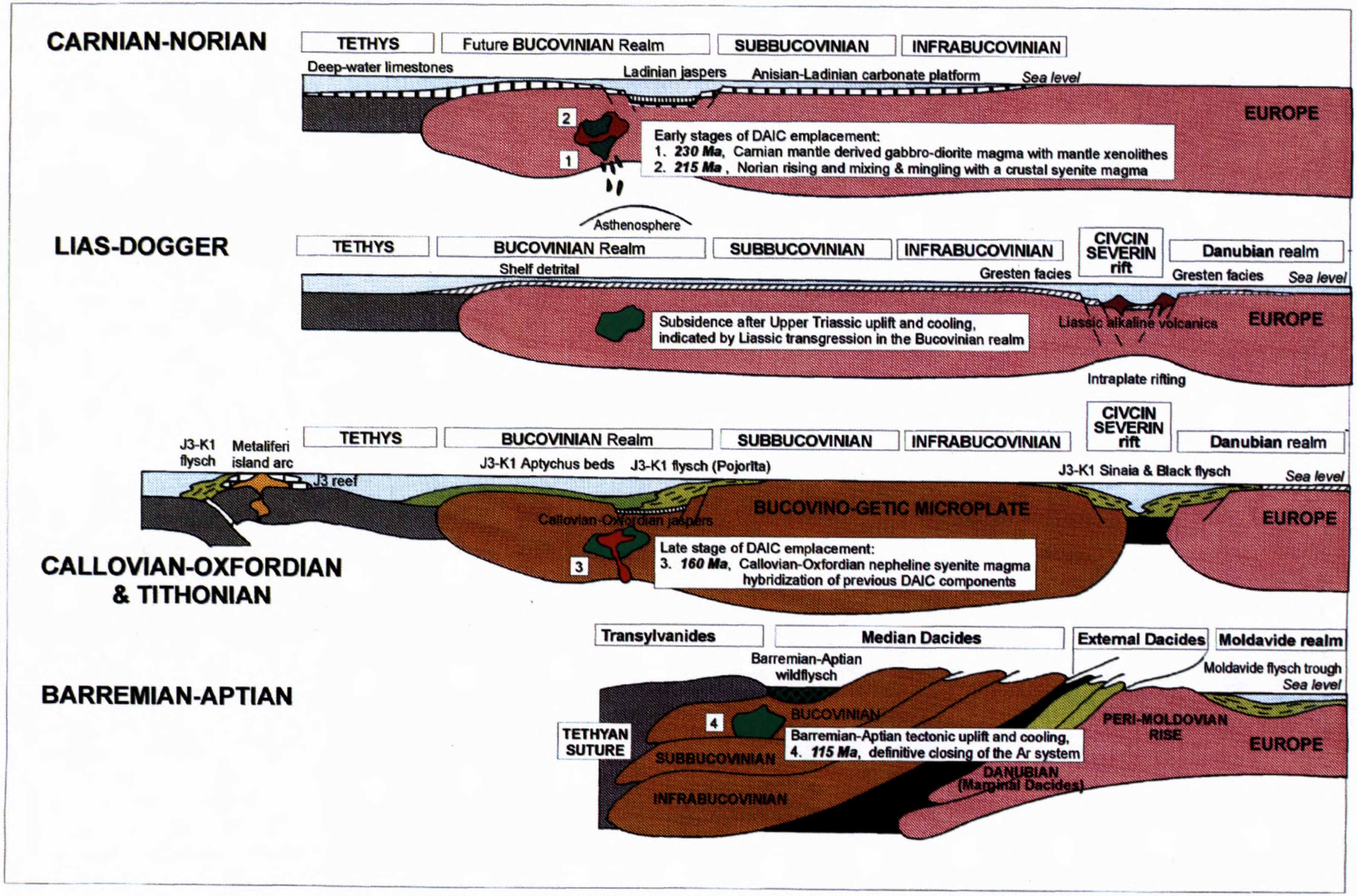

Fig 7 Plate-tectonic model for emplacement and timing of the Ditrau Alkaline Intrusive Complex.

ned ultramafic mantle xenoliths, represented by olivine bearing pyroxenites. These rocks were accommodated to crustal conditions by metasomatic changes with the gabbroic magma and by partial hydration; they were partially or completely transformed into hornblendites by „amphibolization".

c.215 Ma - Upper Norian *(216-212 Ma overlapping interval of K-Ar ages for biotite of granites and for hornblende of hybrid gabbro-diorites, hornblendites).* The gabbro-diorite mass, probably in a subsolidus state, rose and penetrated the crustal syenitic magma in the crust. Under these dynamic conditions magma mingling and magma mixing produced a large variety of intermediary hybrid rocks. Prevailing oriented textures in most pre-nepheline syenite rocks are consistent with these dynamic conditions at a relatively deep crustal level. Sheeted structures and lenticular bodies of mafic rocks, enclosed in foliated syenitic rocks, strongly suggest a mingling of the two magma types. Magma mixing produced a continuous transition from alkali diorites to syenites. A large variety of foliated hybrid monzodiorites and monzonites occur in the transitional zone. Concomitant assimilation of quartz rich crustal rocks gave gradual transitions to quartz monzonites and quartz syenites. For granitic DAIC rocks that formed during this stage, a larger crustal assimilation beneath the actual intrusion level may be assumed. Veining by granite-aplitic rocks supports this interpretation.

c.165-160 Ma - Callovian-Oxfordian *(165-155-Ma overlapping interval of K-Ar whole rock ages of tinguaites with biotite and nepheline K-Ar ages from nepheline-syenites, muscovite, biotite and feldspar ages from syenites and hornblendites, biotite ages from hornfelses).* A mantle derived nepheline-syenite intrusion, formed by partial melting, intruded as a „central stock", but also penetrated laterally towards marginal parts of the massif and veined all previously formed DAIC rocks. During late stages it developed locally to a pegmatoid facies. Mafic foid-rocks („ditro-essexite", a comprehensive term for plutonic rocks of essexitic and theralitic chemistry, proposed by Streckeisen, 1952) formed through hybridization and partial metasomatic substitution of the previous gabbro-dioritic and monzonitic rocks with prevailingly oriented texture. The magmatic activity ended by late tinguaite veins. The nepheline-syenite event may be correlated with the Jurassic extensional stage that produced a separation of the Bucovino-Getic microplate from the European margin by the opening of the Civcin-Severin rift- and spreading-system (External Dacidic Rift acc. to Sandulescu, 1984). Inside the Bucovino-Getic microplate theses Jurassic extensional conditions are recorded in the Bucovinian sedimentary cover by Callovian-Oxfordian radiolarites. Later, the deeps were filled by Upper Jurassic - Lower Cretaceous flysch sequences. The nepheline-syenite emplacement ends subsequent to the Lias alkaline volcanism that was active to the south (Holbav), on the Bucovinian margin near the Civcin-Severin rift system.

Cooling up to c.135 Ma - Berriasian *(140-130 Ma frequency peak for biotite, feldspar, and whole rock K-Ar ages recorded in prevailing altered nepheline-syenites and syenites, but also in granites, gabbro-diorites, hornblendites and hornfelses).* A cooling period lasting about 20-25 Ma, supports the assumption of a deep crustal intrusion level. Late- and post-magmatic hydrothermal-metasomatic alterations produced peculiar varieties of nepheline syenites and pegmatites with cancrinite and sodalite („ditroit", term proposed by Zirkel, 1866 for a variety of biotite-bearing nepheline syenite with cancrinite, primary calcite and sodalite along fractures).

Nappe transport and uplift up to c.115 Ma - Aptian *(120-110 Ma frequency peak for youngest biotite, feldspar, nepheline and whole rock K-Ar ages in nepheline-syenites and syenites).* A final closing of the Ar-system through cooling below Ar release temperatures is assigned to the tectonic uplift. It may be inferred that hydrothermal alteration (liebneritization) and mineralization developed before this time. A Meso-Cretaceous uplift of the DAIC is shown by its uppermost (Bucovinian nappe) position in the pre-Cenomanian nappe pile of the Central Eastern Carpathians.

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Petrology and stratigraphy of the Meliaticum near the Meliata and Jaklovce Villages, Slovakia

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Abstract. Problematics of the Meliaticum, Meliata Ocean and the other questions that are closely connected with them have a prominent place not only in the Carpathian, but in the Alpine geology as well.

The present paper brings new contributions to this body of knowledge. It deals with the investigation of Meliaticum in the vicinity of the Meliata village (SW of Gemericum) and in the wider surroundings of the Jaklovce village (NE margin) (Fig.1).

The vicinity of the Meliata village represents tectonic half-window (Meliata tectonic window) whose rocks contain geological structure complicated by younger thrust tectonics. The Meliata Unit crops out as repeated discontinuous tectonic slices in this window. It is chiefly composed of the Jurassic deep-water shales. In this matrix various large blocks of older Triassic rocks occur. The shale slices were most likely accumulated in an accretionary wedge.

The shales contain sparse thin intercalations of breccias and sandstones, as well as of thin-bedded radiolarites, which also form olistoliths in shales.

The breccias contain mainly clasts of limestones, among which shallow-water limestones prevail. Other carbonate rocks are represented by metamorphosed limestones. Their metamorphism preceeded the formation of the breccia. Also found as clasts in the breccias are cherts and radiolarites. Volcanic rocks of various textures and chemical composition are also important clasts. Claystone lithoclasts in the breccias were derived from the underlying beds.

Radiolarian microfauna from radiolarites represent the stratigraphic range of Middle Bathonian - Early Callovian (Unitary Association Zone: U.A.Z. 6 - U.A.Z. 7 according to the latest biozonation of Baumgartner et al., 1995). The youngest assemblage of the Meliata village area was found in the uppermost part of the Meliata Unit type locality (Kozur & Mock, 1985) and was assigned to Late Callovian-Early Oxfordian (Kozur et al., 1996).

The Meliaticum at the Jaklovce village area is also represented by Jurassic melange. Claystones, siliceous shales, argillites and sandstones form its matrix. Coarse-grained sandstones to microbreccias and conglomerates are a less common part of the matrix. The Jurassic age of the matrix rocks is shown to be Middle Jurassic (Kozur & Mock, 1995) by fragments of belemnite rostra and by radiolarians from a layer of radiolarites in the matrix shales.

Pale, shallow-water, metamorphosed Honce limestones, pelagic cherty limestones, dolomites, basalts, radiolarites, serpentinites and perhaps clastic sediments of Early Triassic age represent the most common melange olistoliths. Olistoliths of Jurassic radiolarites have not yet been found in this area, but serpentinites and basic volcanic rocks are frequent in comparison with the Meliata area. Metabasalts are geochemically most similar to N-Morb (enriched mid-oceanic ridge basalts) types (according to minor element distribution) and indicate their origin to have been in marginal or back-arc basin.

Eight samples generally from Meliata area were analysed for heavy mineral contents. The results are complemented by samples from Florianikogel, Austria (Eastern Alps) and Margecany (northern occurrences of Meliaticum). The data are grouped into two different assemblages. Assemblage No.1, found in the siltstones of Middle Jurassic age from Meliata and in the sandstones from Florianikogel locality, is dominated by garnet and apatite, as well as by presumably authigenous barite. In these samples, some lesser amount of chromium spinels was also found. The apparent similarity between the Meliata and Florianikogel samples is noteworthy. Assemblage No.2, found in the sandstones and quarzites from the Meliata and Margecany areas, contain only the most stable minerals, e.g. tourmaline, zircon and rutile (without chromium spinels). These samples, however, are of uncertain age and position within the meliatic rock complex.

Key words: Western Carpathians, Meliaticum, Triassic, Jurassic, sedimentology, basalts, radiolarians, heavy minerals.

A. Introduction

The problems of the Meliaticum, Meliatic Ocean, the question of its eastward and westward prolongations, the problems of Cimmerian collision and suture zone, the temporal and spatial relationships with other mobile zones, e.g. the Penninic Ocean and/or its individual troughs (South and North Penninic), Pieniny Klippen Belt, Vardar Zone or Southern Tethys are all questions actively being debated around the Alpine Europe.

The Meliatic topic also has a prominent place in understanding of the Carpathian geology. During the last two decades, considerable progress has been achieved. However, there are still many unresolved problems and unanswered questions. Therefore, in the early nineties our team decided to contribute to the knowledge of the Meliaticum within the project "Geodynamic evolution and deep structure of the Western Carpathians". Key areas, in which also our investigation was concentrated, are near Meliata village and the wider surrounds of Jaklovce village. The first site lies southwest of the Gemeric Superunit, whereas the second occurs at its NE margin. The positions of these localities provide contributions to the solution of one of the key questions in the Western Carpathians: do the "northern" Meliatic occurrences represent an independent suture zone north of the Gemeric Superunit or are they just remnants of an obducted Meliatic nappe? This question was already treated by Kozur & Mock (1995, 1996, 1997) and Kozur et al. (1996), by which also some preliminary results of our investigation were mentioned. This paper presents the detailed petrological, sedimentological and paleontological data, obtained during the works on the aforementioned project.

B. Meliata unit in its type locality and vicinity

1. Geologic and tectonic setting

The area of Meliata village is the most important occurence of the Meliatic Unit; although it also has good outcrops, most of them, however, were not studied in detail until the early ninetees. The attention of numerous geologists was focused mainly on this area; several exploration bore-

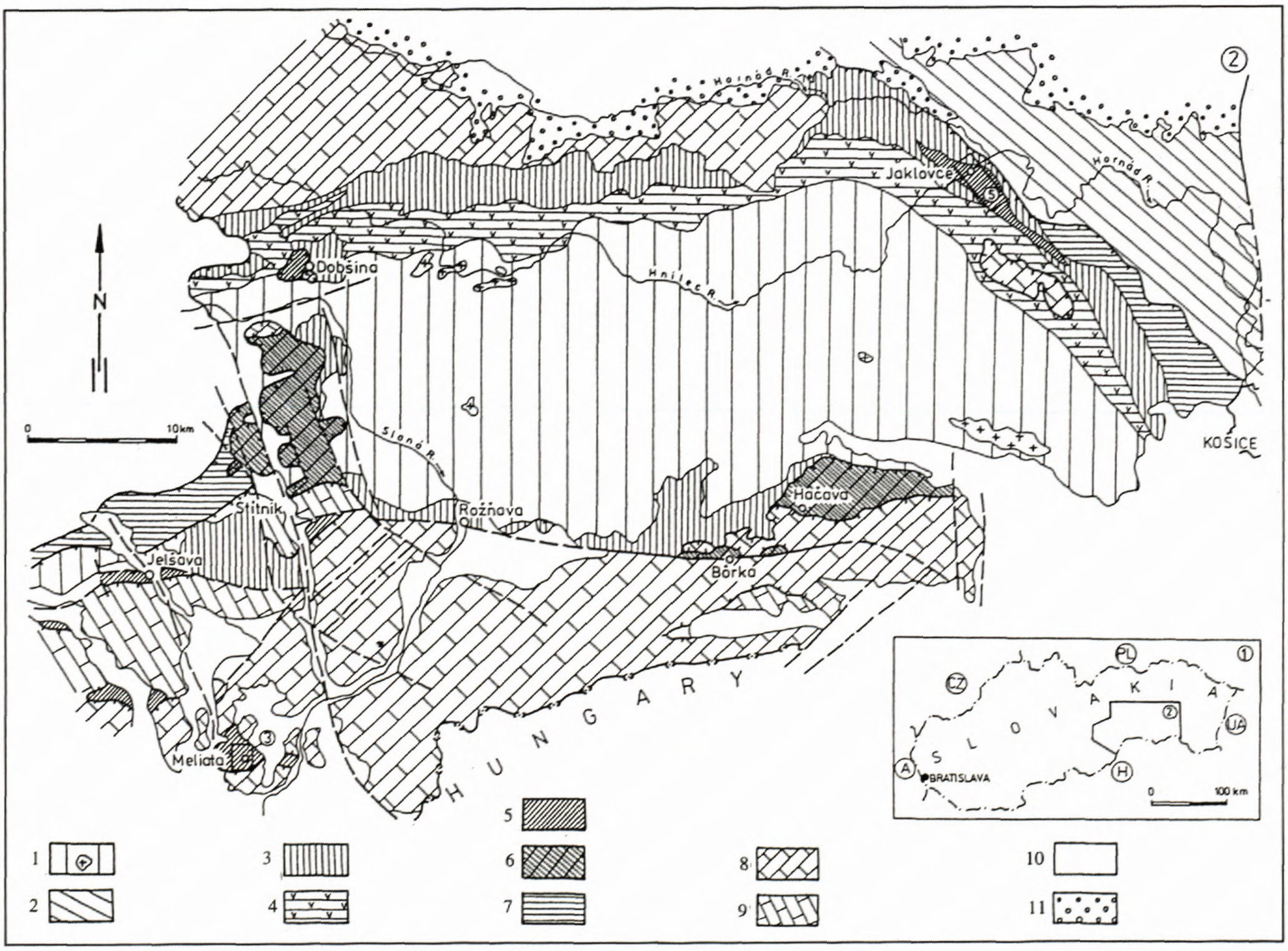


Fig.1 Position of the studied areas (see Fig.2).

Fig.2 Simplified scheme of tectono-stratigraphic units in the SE part of the Western Carpathians.

1 – Gemericum Gelnica Group, 2 – Veporicum, 3 – Gemericum Late Paleozoic, 4 – Gemericum Rakovec group, 5 – Meliaticum, 6 – Bôrka nappe, 7 – Ochtiná and Črmel unit, 8 – Silica, Stratená nappe, 9 – Turňa and Slovenská skala nappe, 10 – Quaternary, 11 – Central Carpathian Paleogene

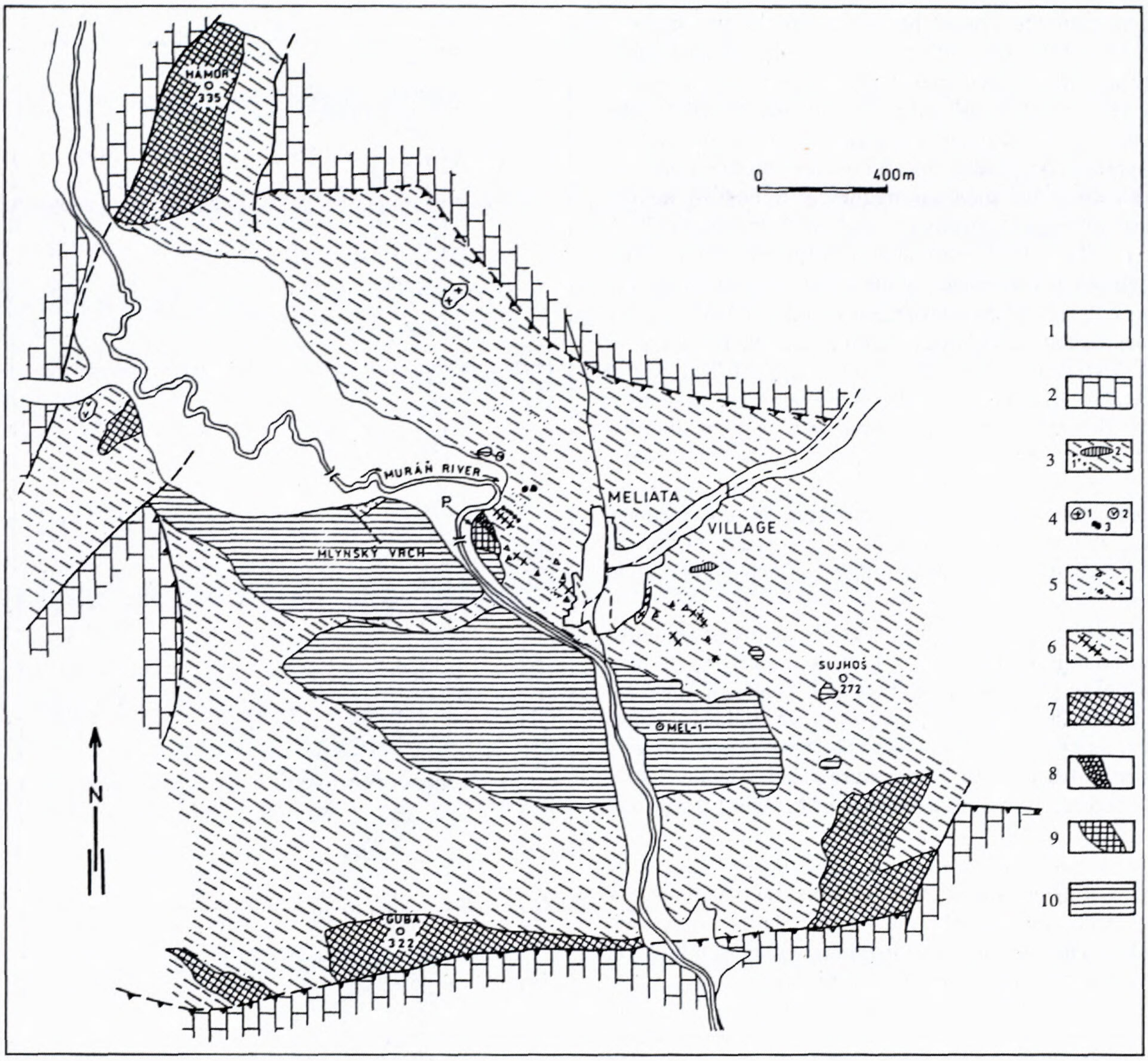


Fig. 3 Geological scheme of the Meliata village area (modified from Mello & al., 1996).
1 – Quaternary, 2 – Silicicum, 3 – 1-debris flow deposits, 2 - block of limestone (? Early Triassic), 4 –1- block of rhyolite, 2-blocks of basalts, 3 – block of arkose, 5 – dark gray and green shales, siltstones, sandstones with lithoclasts of radiolarites, 6 – thin layers of dark gray radiolarites (Calovian - Early Oxfordian) 7 – gray-green and reddish radiolarites (Bathonian-Calovian), 8 – Olistostroma with lithoclasts of Carnian and Norian Limestones (?Liassic), 9 – red radiolarites, shales and limestones (Ladinian-Early Carnian), 10 – light massive crystalline limestones (Pelsonian), P – studied profile see Fig. 4, ⊙ – borehole

holes and one deep structural borehole (Mel-1) were drilled here. The Meliata Unit of this area represents a tectonic half-window (the Meliata tectonic window), which has a complex geological structure, as is evident from the map of Mello et al. (1996) and from the material coming from the deep borehole (Straka et al., 1984; Straka, 1986). The borehole was, however, interpreted incorrectly. Fejdiová & Ondrejičková (1992) proved that the dark shales in the 1718 - 1900 m interval, originally considered to be the Early Triassic of the Silica Nappe (e.g. Straka, 1986), represent in fact the Jurassic deposits of the Meliata Unit. From the siliceous shales at 1750-1900 m they obtained well preserved Jurassic radiolarians.

The Meliata Unit in the Meliata tectonic window crops out discontinuously over an area of about 5 km^2. To the south it is present at Guba hill (lined by the Hraničná dolina valley) and on the north it forms Hámor hill (Fig. 3).

The field exploration showed that the Meliata Unit all around the window is chiefly composed of Jurassic deep-water shales, the slices of which are repeated several times. They comprise also of various large blocks of older, Triassic rocks. Whether they form olistoliths or tectonic lenses, is in some places indeterminable. The shale slices were most likely accumulated in an accretionary wedge (imbricated thrust sheets).

Jurassic rocks, representing the melange matrix in the Meliata area, underlie a large area south and southwest of the village, toward Sujhoš hill (272 m). They are well exposed directly at Meliata village, at a small gipsy settlement near the protestant church (at the turning of a field road from the village center to the Meliata mill). They are represented mainly by dark-grey to greenish-grey clayey shales, siliceous and laminated shales, grey and greenish sandstones and argillites, and rarely also by fine-grained polymictic conglomerates and breccias. The lamination in the shales is frequently formed by admixture of silty quartz, muscovite and rarely by biotite (Pl. I, Fig. 1). The latter is commonly chloritized. At the northern margin of the village, in the clayey shales also poorly preserved radiolarians have been found (Pl. VIII, Fig. 6). Autochthonous radiolarites, forming thin intercalations or even clasts in the shales, are also widespread. They are of the Middle Bathonian - Early Oxfordian age (see chapter B.5). The radiolarites are commonly tectonically disrupted (Pl. I, Fig. 4). They contain rare detrital quartz grains, and silt-sized mica flakes. The presence of rhombohedra of epigenetic Fe-carbonates is conspicuous. Where the radiolarites contain an increased portion of clayey matrix, they should rather be called radiolarian shales.

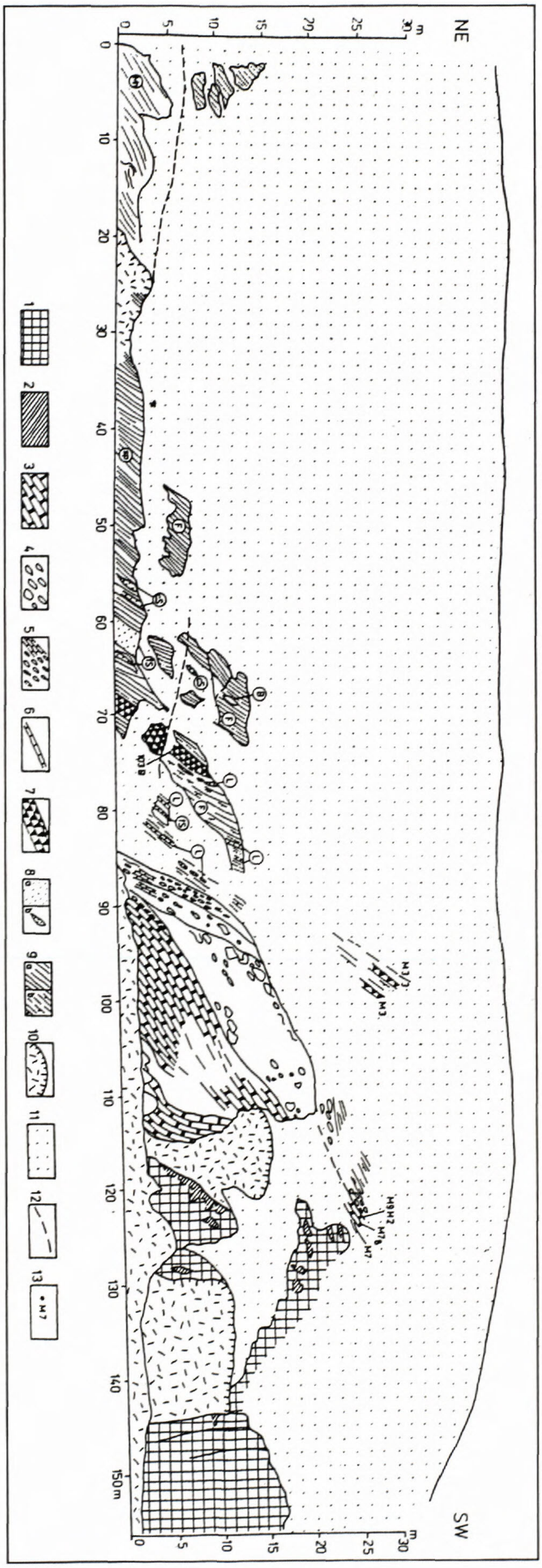
The Jurassic radiolarites occur also as megaolistoliths as at the hills Hámor (335 m) that is also partly formed probably by Triassic radiolarites, and Guba (322 m). Jurassic radiolarites possess greyish-green, reddish, ochre-yellow and greyish-blue colour. The reddish ones usually contain a detrital quartz admixture. They contain poorly preserved radiolarian assemblages of Middle Jurassic age (Kozur et al., 1996) (chapter B.5).

Some slump structures and boudinage of the deep-water sediments occur locally. Important sedimentary components are also Mn and Fe rich shales, lenses and nodules. The presence of olistoliths, either singly or in olistostromes, is characteristic for this area.

Pale, crystalline Lower Anisian Honce limestone, forming a large outcrop in a steep slope along the Muráň river 500 m south of Meliata, evidently represents a big block (olistolith) in the Jurassic rocks (the deep borehole Mel-1 penetrated through this block). Individual blocks of

Fig.4 Sketch of the outcrop section on the left bank of the Muráň river near the Meliata village (the Meliata Unit type profile).

1 – light coloured metamorphosed Honce Limestone (Early Anisian), 2 – reddish Žarnov limestone - often as fissure filling in the underlying limestones (Pelsonian), 3 – red and partly green ribbon radiolarites and silicified limestones with intercalations of shales (Ladinian), 4 – unsorted and nearly matrix free breccia (olistostrome) composed of predominantly Late Triassic limestone clasts, 5 – breccia (olistostrome) composed of boudinaged clasts of grey grained limestone of Late Norian age, 6 – olistolites of grey (Early Jurassic?) limestones (L), 7 – intercalations and/or olistolites of grey radiolarites (Late Callovian - Early Oxfordian), 8 – a. fine-grained sandstones (fS), b. lens-shaped layers of coarse-grained sandstones (cS) or breccias (B), 9 – greenish-grey shales (a), calcareous shales (b), in some places spotty (sp), fucoid (F) silty and sandy shales. Occurrence of manganese admixture and concretions (Mn), 10 – slope debris, 11 – superficial deposits, 12 – footpath, 13 – some studied samples



this limestone were formerly considered to form one continuous layer with a thickness of several hundreds meters. Also, the white crystalline limestone at the base of the Meliata Unit type locality has been considered to belong to this layer. On the basis of the field study we believe that the limestones on the opposite bank of the river are independent Triassic blocks in the shaly Jurassic rocks. The largest block forms Mlynský vrch hill (287 m). The limestones are light grey, metamorphosed, foliated and with ductily deformed calcite grains. In the Mel-1 borehole, Early Anisian conodonts were found in the Honce Limestone (Straka, 1986; Kozur, 1991).

Smaller blocks of pale Triassic dolomitic limestones, 150 m north of the Meliata type profile (text Fig. 3), are, apart from the previous ones, only anchimetamorphosed. Their original structure was more obliterated by dolomitization than by metamorphism. In several samples original structures were preserved; they were intrasparites (Pl. VIII, Fig. 1) to pelsparites. Rarely also poorly preserved foraminifers *Meandrospira iulia* (PREMOLI SILVA) and algal remnants are visible. Authigenic plagioclases (also some roc-turné compound crystals) occur frequently close to stylolites. The foraminifers indicate a Pelsonian age.

Besides the white Lower Anisian limestones, the most frequent blocks (olistoliths) are the red radiolarites. They make up for instance, part of Hámor hill (335 m). In much-covered terrain these resistant rocks form a conspicuous relief. The presence of the Jurassic shales among these harder blocks was verified at several places by digging. This association is observable also in the borehole material, e.g. in the Držkovce borehole (SW of Držkovce village, situated NW from Meliata) there were thin intercalations of Jurassic shaly matrix embedded between the Triassic clasts (e.g. at the 767 m depth).

The melange also contains rare smaller blocks of dark grey limestones. They were found just SE of Meliata village. These are laminated, in part folded, recrystallized limestones with barely identifiable biodetritus represented by calcified radiolarians and filaments. In some more detrital laminae, ostracods (Pl. VIII, Fig. 5), calciclasts, detrital quartz and authigenous plagioclases were identified. The presumed age of these rocks is Early Jurassic.

Just at SE margin of the village (Fig. 3), a block of thin-bedded dark grey to black limestone was found. The limestone is recrystallized; its original texture is preserved just in relics. It contains also detrital quartz (less than 1%) and epigenetic minerals (mainly pyrite, Fe-carbonates and authigenic feldspars). From the biodetrital components, some ostracods and echinoderm ossicles were identified in thin sections. Additionally, pelloid grains and some foraminifers *Cornuspira* sp. and *Hoyanella* sp. were also found (Pl. VIII, Fig. 2). The foraminifers indicate an Early Triassic age of the rock, i.e. it represents still a pre-rift component of the Meliatic Unit.

NW of Meliata behind the type profile of the Meliatic Unit, a block of grey arkosic arenite was found (Fig. 3). It comprises mainly of quartz and feldspar (predominantly plagioclases) grains; rarely also muscovite, accessoric minerals (zircon, tourmaline), clasts of low-grade metamorphosed rocks and rhombohedra of epigenetic carbonates are present. The cement is calcitic. The abundance of the individual components are: 66% quartz, 32% feldspars, 2% lithoclasts. The grains are not sorted, their average size is about 0.3 mm and their maximum is 5 mm.

Approximately 800 m N of the Meliata type profile (Fig. 3) is a block of light grey paleorhyolite measuring several tens of meters. Macroscopically, it is hardly distinguishable from radiolarites and other silicites. Also, the weathering colour is ochre-grey, just like that of the silicites. It contains grains of magmatically corroded quartz, K-feldspars and devitrified volcanic glass (Pl. I, Fig. 2). The quartz grains are slightly undulatory and faintly cracked. The feldspars are sericitized along the cleavage plains. A presumed age of the rock is Paleozoic, similar to the arkosic arenite described above.

2. Detailed sedimentological description

The section in the Meliata Unit type locality ("Meliata Series", named by Čekalová, 1954) is situated north of the Meliata mill, on the left bank of the Muráň river. The section is about 220 m long and locally up to 25 m high natural outcrop.

The type section is mentioned in many publications. It is interesting that in the first papers of Homola (1951), Čekalová (1954) and Bystrický (1959) the presumed Carboniferous (now Anisian) white crystalline limestone was not considered to be a part of the section with shales, grey limestones and red radiolarites, later recognized at the Meliata Unit. Also, based on field exploration and shallow boreholes drilled for the intended construction of a dam in the Muráň narrows, it was found that at the uppermost portions of the white crystalline limestone there are more and more red shales, rip-up clasts and red limestones (now Pelsonian) that are part of an overlying stratigraphic member. They were also assigned to the Meliata Unit, and their age was inferred to be Upper Permian and/or Lower Triassic (Nemčok, 1957; Bystrický, 1959, 1964).

Since the first conodonts were found at this locality (Kozur & Mock, 1973 a,b) and the Middle to Upper Triassic age of some members has been proven, the locality was mentioned in several supportative publications. They did not, however, substantially change the view from 1973 (Mock in Mello, 1975; Mock, 1980; Bystrický, 1981; Mello et al., 1983; Kozur & Mock, 1985).

In 1992, the type profile was re-examined at a 1:100 of scale. At key sites, the covering vegetation and soil were removed. About 200 samples were examined for microfossil contents, microfacies, heavy minerals, sedimentology and geochemistry. Based on these examinations, a new view on the structure of the profile was constructed (Fig. 4):

a.) The base of the section (the base of the unit, as was presumed until 1992) begins with thick white crystalline Honce Limestone (most probably metamorphosed Steinalm Limestone) of the Lower Anisian. In the upper part, the red shaly intercalations of the Žarnov Fm. are present. Their quantity increases upward, where a red limestone appears, filling neptunian dykes in the Honce Limestone.

Locally, the Žarnov Limestone contains angular clasts of the white crystalline limestone, documenting a disintegration of the former shallow-water carbonate platform. The red limestones are also recrystallized but less extensively than the underlying pale marbles (due to their different composition). The original structure was preserved in only rare cases. They represented biomicritic wackestones with filaments and calcified radiolarians (Pl.VIII, Fig. 3). Despite the metamorphism, they yielded a rich Pelsonian conodont fauna. The Pelsonian age was determined also for several layers of red micritic limestone in the uppermost part of the white crystalline limestone block (its Lower Anisian age was shown by the Pelsonian neptunian dykes and by conodonts obtained from similar limestone types in the Mel-1 borehole (Gaál in Straka et al., 1984). In the upper part of the outcrop, the Pelsonian limestone is distinctly laminated. The lamination indicates how were the fractures oriented during deposition. Some of them were parallel to the bedding of the underlying pale limestone.

b.) Above the white crystalline and red Anisian limestones, radiolarites of various colours (predominantly red) follow in the section (Ladinian). Their contact with the underlying limestone is, however, covered by debris and soil (at 125 m in the sketch of Fig. 4). Since 1973, a conformable continuation was assumed, though with a small gap. The main reason of this opinion was the similar dipping of both parts of the section. Under the debris cover between these outcrops, however, greenish Jurassic shales were uncovered (samples M-7, M-9), which indicate that the Anisian limestones and following Ladinian siliceous limestones and radiolarites are just blocks (maybe olistoliths) in the Jurassic matrix and the formerly presumed continuity of the profile was unwarranted. The misleading similar dips of the blocks most probably resulted from their natural orientation in the olistostrome along their longer axes determined by the bedding planes. It is possible that the upper part of the white crystalline limestones also consists of several blocks separated by thin Jurassic shale interlayers. However, some tectonic disturbance by younger tectonic movements is not excluded.

In the variegated radiolarites, pink and red colours predominate. Among them, silicified deep-water limestones also occur, frequently with big red chert nodules or layers. In the lowermost part a very short exploration gallery was dug, since this portion consists of dark grey radiolarites with Fe oxide coatings. According to radiolarian fauna (Kozur et al., 1996) the radiolarites are Ladinian.

c.) Between the variegated radiolarites and the overlying units, a sharp contact occurs in the form of a thin intercalation of greenish claystone (0-7 cm). It is followed by an olistostrome layer (6 m in the upper part of the outcrop, above 130 m in the sketch of Fig. 4) composed of lithoclasts of grey, grained and cherty Carnian limestones (10-30 cm size), also an angular block of the red radiolarite (chert, 20x10 cm in size) was found. The olistostrome is locally strongly squeezed with a minimum content of matrix, resembling a coarse nodular limestone (Pl.VII, Fig. 3). As a rule, the limestone clasts are subangular, whereas the radiolarite clasts are angular. In the nodular-like portion, the clasts were probably tectonically rounded. Numerous grey limestone samples yielded Carnian conodont fauna, hence a normal stratigraphic succession over the Ladinian radiolarites was inferred.

This relatively thin layer with olistoliths thickens downwards, reaching over 3 m at the foot of the profile. We infer that the aforementioned variegated radiolarite block is also a component of this olistostrome.

d.) Higher above the carbonate olistostrome, the content of dark calcareous shales increases (10 m) with decrasing quantity of the limestone olistoliths. In some of them, Carnian and Norian conodonts were found (Kozur & Mock, 1973; Mock in Mello, 1975). The shales are, however, of Jurassic age, not Upper Triassic (Kozur & Mock, 1973) or Ladinian (Planderová in Mello et al., 1983) as was proposed in the past. They are dark and calcareous, even with discontinuous layers (not olistoliths) of grey and bluish-grey limestones, free of conodonts or any stratigraphically valuable fossils. These rocks, together with the shales, are inferred to belong already to the Jurassic.

e.) Deposition of the grey calcareous shales in the upper part of the section gives way to a huge complex of non-calcareous claystones, in places with thin layers of grey and greenish-grey radiolarites. They contain radiolarian assemblages of Middle Jurassic-Early Oxfordian age (see chapter B.5). The lower part of this formation is extensively bioturbated. A spotty appearance of the rocks resemble the Lower Jurassic "Fleckenmergel" facies (Pl. VII, Fig. 2). In the claystones, a 130 cm thick layer (not olistolith) of thin-bedded grey radiolarite occurs. From this upper part of this sequence Modrová (1980) obtained radiolarians, that were introduced by Kozur & Mock (1985) as the first paleontological proof of the Jurassic in the Meliata Unit. The Late Callovian-Early Oxfordian radiolarian fauna is excellently preserved (Kozur & Mock, 1985; Kozur et al., 1996).

These radiolarites in the type profile are overlain by greyish-green to grey, often distinctly laminated shales with thin layers of sandstones to microconglomerates of similar colour. The latter probably represent shallow channel fillings (Pl. II, Fig. 2). This formation can be traced a further 70 m. In the claystones, some Fe-chlorite laminae were found (Pl. VII, Fig. 4; Tab. 1), likely related to synchronous volcanic activity (probably slightly metamorphosed tuffitic intercalations). Some trace fossils (*Helmintoides*) and a problematic fossil outprint (probably of a poorly preserved ammonoid) were also found in the shales. Graded-bedding in the sandstones and microconglomerates indicate that the formation lies in a normal position. These parts were also examined for heavy minerals (see chapter F). The whole formation is nearly free of $CaCO_3$ and has signs of deep-water sedimentation below CCD. In the uppermost portions of the profile shale layers with higher Mn concentrations (Mn-oxides forming nodules and interlayers) occur in several horizons.

The Jurassic shale complex, covered with Quaternary sediments, continues behind and above the type profile northward as far as Hámor hill .

Tab. 1 Chlorite analyses from the Meliata type profile

metatuffite lamina in the shales				isolated grains from the shales		
sample	mel16-1	mel16-2	mel16-3	mel4	mel5	mel6
SiO_2	25.5	25.15	25.03	24.96	29.3	25.63
TiO_2	0.01	0.05	0.04	0.02	0.19	0
$Al2O_3$	19.64	18.61	19.24	21.33	21.92	22.9
FeO	29.94	30.98	31.88	25.08	22.55	24.74
MnO	1.33	1.33	1.31	0.23	0.35	0.15
MgO	10.21	8.96	8.63	11.96	8.57	13.16
CaO	0.03	0.02	0.03	0.01	0.2	0.04
Na_2O	0	0	0.02	0.01	0.02	0.04
K_2O	0	0	0	0.01	0.82	0.1
H_2O	11.08	10.98	10.96	11.34	11.23	11.42
total	97.74	96.08	97.14	94.95	95.15	98.18
structural formules						
Si IV	2.83	2.87	2.83	2.8	3.31	2.75
Al IV	1.17	1.13	1.17	1.2	0.69	1.25
T site	4	4	4	4	4	4
Al VI	1.4	1.38	1.39	1.62	2.23	1.64
Ti	0	0	0	0	0.02	0
Fe +2	2.78	2.96	3.01	2.35	2.13	2.22
Mn +2	0.13	0.13	0.13	0.02	0.03	0.01
Mg	1.69	1.53	1.45	2	1.44	2.1
Ca	0	0	0	0	0.02	0
Na	0	0	0	0	0	0.01
K	0	0	0	0	0.12	0.01
O site	6	6	6	6	6	6
O	10	10	10	10	10	10
OH	8	8	8	8	8	8
Charge	0.23	0.26	0.23	0.42	1.45	0.36

Element proportion recalculated on basis of 10 cations (after A. M. Afifi & E. J. Essene, 1988).
* $FeO + Fe_2O_3$ formally as FeO

3. Petrologic analysis of the detrital components in the microconglomerates and fine-grained breccias (except basalts).

Samples of two detrital horizons were analysed petrologically in thin sections:

a.) Samples of a coarse-grained sandstone to carbonatic breccia (see Fig. 4, cS). Carbonates represent the dominant component of the breccia. They can be divided into two groups.

The larger group comprise metamorphosed limestones (Pl. VI, Fig. 3, 4) that are partially replaced by authigenic feldspars (mainly albite). The degree of replacement as well as size of the feldspar grains is variable. In some instances, the authigenic feldspars are concentrated at the surface of the detrital grains.

The second group of the limestone lithoclasts is free of the authigenic feldspars. Though their matrix, as a rule, is partly recrystallized (probably also dolomitized), their original character is still discernible. They are oomicrites, oosparites (Pl. III, Fig. 6), pelsparites (Pl. III, Fig.7, 8), micrites (some with pseudomorphs after evaporites - Pl. VI, Fig. 1) and micrites without allochems. Also, some echinoderm ossicles (Pl. III, Fig. 4) and rare isolated ooids (Pl. III, Fig. 1) and oncoids (Pl. III, Fig. 5) occur among the clasts. Some of the crinoidal ossicles are also albitized.

Very rarely also, some detrital grains of intermediate volcanic rocks were found, with ophitic intersertal texture. Some grains, formed exclusively by feldspars, possess spheroidal shapes. Some individual grains of monocrystalline to polycrystalline detrital quartz were also found. Rip-up clasts of underlying claystones, with a variable content of silty admixture, are a current component of the psephite (Pl. III, Fig. 3). Pyrite is a usual authigenic mineral; it replaces the grains but occurs also in the matrix.

The content of carbonates in the analysed breccias ranges between 60 and 80%; the feldspar-free limestones occur in a 6-23 % range. The lithoclasts of claystones and clayey shales (the rip-up clasts) make up about 10% of the rock volume and the matrix 10-27%.

b.) Sample of a fine-grained polymictic breccia (see Fig. 4, fS), (Pl. II, Fig. 3). Its dominant components are clasts of volcanic rocks (see the next chapter) and some radiolarites (also Triassic - Pl. VI, Fig. 2). Limestones are also frequent in the breccia. They are mostly metamorphosed; in rare cases, some relics of their original texture were preserved. However, some pressure-deformed and slightly recrystallized oosparites, but free of strong metamorphic overprint, were also found. In some grains of a siliceous limestone, recrystallized radiolarians and thin-shelled bivalves were observed. Also, sparse grains of sandy to silty limestones were found but their original structure was also obliterated by the metamorphism. The metamorphosed limestones are frequently albitized (albite verified by microprobe), with albite grains concentrated, in some instances, at the surface of the lithoclasts or inside them. This invokes a theory that some grains of the feldspathic rocks might represent completely albitized limestones. Keratophyres are part of feldspathic rocks. They contain feldspathic spheroids (Pl. VII, Fig. 1) with brownish flaky minerals (probably biotite, according to some hexagonal cross-sections). Some quartz-feldspatic rocks, which may also represent some altered sediments, were also found.

Some grain margins are rimmed by fibrous calcite or chlorite (less common) that grow into the voids originated due to grain deformation. In this calcite the authigenic albite grains originated later.

The rip-up clasts of the underlying clayey shales and siltstones frequently occur in the breccia. It indicates an erosional character of the current that transported the detritus. The newly formed chlorite flakes that occur in the underlying and overlying claystone beds were not found in these rip-up clasts.

4. Detrital basaltic material analysis

Close to the type profile at Meliata, a small (about 2x1.5 m) outcrop of breccia was found, that also contains also some clasts of basaltic rocks. It probably represents a "diabase body" already mentioned by Kantor (1955) that occurrs approximately 200 m north from the type profile on a vegetation-covered slope above the left bank of the Muráň river.

The basaltic material is chiefly represented by fine-grained varieties (mainly more or less recrystallized volcanic glass); some more ophitic types are sparsely preserved. The devitrification of volcanic glass is shown by of fan-like aggregates of acicular plagioclase (up to 80%). In one instance, a clast incorporated to the breccia appeared to represent originally a volcanic breccia. Basalts with intersertal structure are also widespread. The clasts are largely spilitized, which is shown by newly formed chlorite and carbonates in veinlets, fine-grained aggregates and as independent xenomorphic grains. The ophitic texture was observed in just two clasts. In one of them, the plagioclases are replaced by epidote pseudomorphs, with a preservation of the original magmatic texture. The basaltic material in the breccia originated probably as a marginal part of a lava flow.

Other basaltic clasts are frequently found in detrital layers directly in the greenish Jurassic shales in the Meliata type profile (chapter B.3).

Although it does not represent a homogenous magmatic rock but clasts in detrital layers, miscellaneous magmatic rocks can be distinguished (Pls.IV, V):

a.) **Non-recrystallized volcanic glass** with amigdales (Pl. IV, Fig.1, 2) is a relatively frequent component. It is a dark-green to black glass with widespread (also non-crystalline) opaque pigment. The amigdales are tiny and possess regular circular shapes. As a rule, they are filled with chlorite and calcite, less quartz.

b.) **Recrystallized volcanic glass** (Pl. IV, Fig. 3, 4, Pl. V, Fig. 1) with signs of formation of intersertal, less arborescent structure, i.e. the rock is composed of microcrystalline plagioclase needles (most likely albite). The rest comprise a xenomorphic aggregate of chlorite and amorphous ore pigment. The amigdales (filled with chlorite and calcite) are frequent; elongated to massive plagioclase phenocrysts can be found also.

c.) **Fine- to coarse-grained intersertal basalts** (Pl.V, Fig. 2) form the majority of the basaltic clasts. The main portion of the rock texture consists of usually subhedral elongated plagioclase crystals; the intergranular spaces are again filled by chlorite. The opaque minerals are present in form of amorphous pigment and, to a lesser extent, as crystals (commonly acicular). Similar to rocks of groups a. and b., the plagioclase phenocrysts and amigdales are present in places.

d.) **Ophitic basalt** (Pl. V, Fig. 3) is a relatively rare component, consisting of big massive plagioclase crystals in various stages of saussuritization. As a rule, they are strongly altered; mineral grains of the epidote-zoisite group appear as a product of this alteration. Pyroxenes were not observed; however, their former presence is indicated by chlorite between the plagioclase crystals. Opaque minerals are again represented by brown pigment or as tiny crystals.

e.) **Dolerite** (?) clasts (Pl. V, Fig. 4) were found in very small amounts. They are strongly saussuritized forming large plagioclase crystals, that were in many cases further albitized. From other minerals, grains of quartz, chlorite, epidote and cubic-shaped mineral (likely pyrite) are present also.

These types were divided to facilitate their description; in fact, continuous transitions appear among them. Based on their petrographic characteristics, they represent different parts of a submarine lava flow: vitreous margins, fine- to coarse-grained intersertal types to coarse-grained ophitic and doleritic (?) varieties forming inner parts of the flow. Although, due to small size and high degree of spilitization, these clasts are inadequate for geochemical analysis, they probably represent an equivalent of the ophiolitic formation of the Meliata Unit defined as Švablica Formation (Hovorka & Spišiak, 1988) or as Bódva Ophiolite Formation (Réti, 1985).

5. Evaluation of radiolarian assemblages

The first radiolarian research of radiolarites in the locality Meliata was described in the paper of Kozur & Mock (1985). On the basis of revaluation of radiolarians from the uppermost part of the type section along the bend of Muráň river (Modrová, 1980) with the large stratigraphical interval of evaluated radiolarians - Triassic - Jurassic) Kozur (l.c.) demonstrated the occurrence of Jurassic in the Meliata Unit (Late Callovian-Early Oxfordian).

The 1992 samples from this section provided radiolarian assemblages, which all showed signs of sorting (size and shape uniformity). The conical, oval and flask-like shapes of small size highly prevailed here. Spumellarians occurred rarely, mainly as fragments. The species *Tricolocapsa conexa* Matsuoka was dominant in all assemblages.

They represented the stratigraphic range of the Bathonian to the upper half of the Callovian (Kozur et al., 1996) and, according to the assemblage described in the paper of Kozur & Mock (1985) the uppermost radiolarite layers were assigned to the Late Callovian-Early Oxfordian (Kozur et al., 1996).

According to the latest biozonation of Baumgartner et al. (1995) the assemblages from the samples of 1992 are of the stratigraphic interval Middle Bathonian to Early Callovian (Unitary Association Zone: U.A.Z.6 - U.A.Z.7).

Sample M-7 (Pl.IX) - U.A.Z. 6 - U.A.Z. 7 - Middle Bathonian - early Callovian (the co-occurrence of *Stylocapsa oblongula* Kocher, with *Stichocapsa robusta* MATSUOKA and *Dictyomitrella* (?) *kamoensis* MIZUTANI et KIDO.)

Sample M-3, M-3/3 (Pl.X) - U.A.Z. 6 - U.A.Z. 7 - Middle Bathonian-early Callovian (the co-occurrence of *Stylocapsa oblongula* MATSUOKA with *Stichocapsa robusta* MATSUOKA).

But, both of these associations lacked the species *Cinguloturris carpatica* Dumitrica or *Eucyrtidiellum ptyctum* Riedel et Sanfilippo, which occurred in the next assemblages from the superposed sample M-103B. Therefore they probably represent the lower part of this range.

Sample M-103B (Pl. XI) - U.A.Z 7 - late Bathonian-early Callovian (the co-occurrence of *Cinguloturris carpatica* DUMITRICA with *Stichocapsa robusta* MATSUOKA).

Tab.2 Distribution of radiolarians in the samples studied from the Meliata Unit type locality

Samples Radiolarian fauna	M-7	M-3	M-3/3	M-103B	G - 6
Acanthocircus suboblongus s.l. YAO					*
Angulobracchia sp.					*
Archaeodictyomitra exigua BLOME	*				
Archaeodictyomitra primigena PESSAGNO et WHALEN	*				
Archaeodictyomitra rigida PESSAGNO				*	*
Archaeodictyomitra sp.		*			
Archaeospongoprunum imlayi PESSAGNO				*	
Cinguloturris carpatica DUMITRICA				*	
Dictyomitrella (?) kamoensis MIZUTANI et KIDO	*		*		
Eucyrtidiellum ptyctum RIEDEL et SANFILIPPO				*	*
Eucyrtidiellum semifactum NAGAI et MIZUTANI	*				*
Eucyrtidiellum unumaense unumaense (YAO)	*			*	*
Eucyrtidiellum unumaense pustulatum BAUMGARTNER			*		
Obesacapsula morroensis PESSAGNO			*		
Parahsuum sp.				*	
Parvicingula dhimenaensis s.l. BAUMGARTNER	*		*		
Parvicingula dhimenaensis ssp. A sensu BAUMG.et al.1995				*	*
Podobursa sp.				*	
Protunuma (?) lanosus OŽVOLDOVÁ					*
Protunuma (?) ochiensis MATSUOKA					*
Ristola altissima major BAUMGARTNER et DE WEVER				*	
Semihsuum sourdoughense PESSAGNO, BLOME et HULL				*	
Spongocapsula palmerae PESSAGNO					*
Stichocapsa convexa YAO	*	*	*	*	*
Stichocapsa robusta MATSUOKA	*	*	*	*	
Stichocapsa sp. E sensu BAUMGARTNER et al. 1995					*
Stylocapsa oblongula KOCHER	*	*	*	*	
Theocapsomma cordis KOCHER		*		*	
Theocapsomma cf. *cordis* KOCHER		*			
Transhsuum brevicostatum (OŽVOLDOVÁ)		*	*	*	
Transhsumm cf. *brevicostatum* (OŽVOLDOVÁ)			*		
Transhsuum maxwelli gr. (PESSAGNO)	*	*	*		*
Tricolocapsa conexa MATSUOKA	*	*	*	*	*
Tricolocapsa plicarum YAO		*			
Tricolocapsa cf. *plicarum* YAO			*		
Unuma latusicostatus (AITA)					*
Unuma sp. A sensu BAUMGARTNER et al. 1995	*				*
Williriedellum sp. A sensu MATSUOKA, 1983		*			
Williriedellum sp.	*				
Zhamoidellum sp.	*				

But the species *Eucyrtidiellum ptyctum* RIEDEL et SANFILIPPO also occurred there. Baumgartner et al. (1995) established its appearance in U.A.Z. 5 (latest Bajocian - early Bathonian), but according to our research, as well as that of other authors (e.g. Yamamoto et al., 1985; Goričan, 1994), this species appears in Callovian.

Therefore this assemblage probably represents the uppermost part of the range of U.A.Z. 7.

The species *Eucyrtidiellum ptyctum* also occurred in the assemblage from the radiolarite in the locality Guba (**sample G-6**) (Pl. XII), NW of the studied section. This assemblage also represents the same stratigraphic interval as the sample M-103B.

The youngest assemblage from radiolarites in the type profile (late Callovian-Early Oxfordian) (Kozur & Mock, 1985) (Kozur et al., 1996) were not found from the samples of 1992.

The assemblages from Jurassic radiolarites in the locality Hamor were relatively poorly preserved. Their species composition showed mostly the large stratigraphical interval of Middle Jurassic age (Kozur et al., 1996).

C. Meliata Unit in the Jaklovce area

1. Previous investigations

The rocks near Jaklovce village (Fig. 5) have long attracted attention of geologists. Of interest to them were "diabases" and serpentinites, rocks that are not common in the Carpathian Mesozoic. They were thoroughly mapped and described by Kamenický (1957). His map remains the best information about the occurrences of these rocks in this complex area.

The basic and ultrabasic rocks were believed to be of Early Triasic age. The "Werfenian with diabases" of Jaklovce was a well-known term. Sediments surrounding the volcanites and serpentinites were also considered to be of Early Triassic age.

However, some controversial data in the descriptions of Kamenický (l.c.) and some of his successors attracted a new generation of investigators to this area. It was namely a problematic radiolarian fauna found in thin sections from the "Early Triassic" rocks, then the recrystallized pale limestones, quarried between Jaklovce and Margecany, that were strikingly similar to those in Meliata and in other known Meliatic localities. It is noteworthy that in the time when the marbles in Meliata were still considered to be of Carboniferous age, those from Jaklovce were, even without any known fossil remnants, attributed to the Middle Triassic (Steinalm Limestone). At the same time, however, the metamorphic difference between these marbles at Jaklovce and the unmetamorphosed limestones of Galmus Plateau (Silicicum s.l.) was explained through narrowing and squeezing of the "north-Gemeridic syncline" in this section and a weak metamorphism of the Triassic rocks.

In the late seventies, Mock (1980) found pink and red neptunian dykes in an abandoned quarry (with marbles and black aphanitic basalt in its upper parts). This material provided some Pelsonian conodonts. Similar dykes were already known from the Meliata Unit. The other rocks such as serpentinites, basalts, red claystones and silicitic shales, interbedded in basalts etc., however, were not known from this unit. Therefore, as with the Meliata Unit, this developement was considered to be an independent Jaklovce Group (Mock, 1980) and presumed to represent a Mesozoic cover of the northern Gemericum. Later, Gaál (1984) and Mahel' (1986) used the term Jaklovce Sequence.

Later, when all the typical Meliatic rocks had been reported from the Jaklovce area, the term Jaklovce Group became unnecessary; the whole sequence was attributed to the Meliata Unit s.s. sensu Kozur & Mock (1985). The red "Werfenian shales" with "diabase" bodies appeared to be red deep-water claystones, siliceous shales and radiolarites of the Middle Triassic age.

New biostratigraphic and geologic data came from an unpublished thesis of Nižňanský (1982), Ištvan (1984) and detailed mapping of Gaál (1984). A slightly simplified geological map of the latter author was also published by Mahel' (1986, p.138). The chaotic and complex geological structure of the area between Kurtova skala Hill and Margecany was divided by him into two sequences, the Jaklovce and Kurtova skala. The latter was considered to be the higher tectonic unit, a nappe remnant of the Middle Triassic limestones of the north Gemeric type (Stratená type - Silicicum s.l.); the lower, Jaklovce sequence, with frequent radiolarites and ophiolites, was considered to be a developement similar to the Meliata Unit. However, the Steinalm Limestones of Kurtova skala Hill are affected by the same (even a higher) degree of metamorphism as the pale Anisian marbles of the Jaklovce sequence of Gaál (l.c.).

The Meliatic Unit in the Jaklovce area also commonly has numerous volcanic and magmatic rocks. They include a wide spectrum of volcanic and subvolcanic "diabases" (many altered) and various types of keratophyres and paleorhyolites. These basic volcanic rocks are dealt with in the separate chapter. The area is well-known mainly by its serpentinitic occurrences with chrysotile asbestos deposits. They form several isolated bodies (blocks) that were either thought to be ultrabasic protrusions or their tectonic emplacements. Most of the basic and ultrabasic rocks represent just the blocks, either olistoliths or tectonic lenses, in the Jurassic subduction melange.

2. New sedimentological and stratigraphical data

The Meliata Unit in the Jaklovce area represents a Jurassic sequence containing numerous detrital components of various size, from tiny clasts in breccias to megaolistoliths. Apart from it, they represent the same types of magmatic, volcanic and sedimentary rocks, predominantly of Triassic age.

The principal type of the Jurassic rocks (matrix of melange) is variegated claystones; they are most frequently grey, greyish-green, commonly laminated shales, but also include red, violetish to beige, noncalcareous to slightly calcareous shales. Siliceous shales with indeterminable radiolarians are widespread also. As a rule, the shales contain silty admixture mainly of macroscopically visible tiny mica flakes. Additionally, some argillites and sandstones are also present. Less frequent are coarse-grained sandstones to microconglomerates and breccias with miscellaneous detritic material. All these rocks were formerly considered to belong to the Lower Triassic. Actually, the Lower Triassic sediments in the Gemer area are similar to the Jurassic ones.

In the shale complex south of the 587.2 m elevation point, about 200 m W of the uppermost part of the large Margecany quarry our team found thin intercalations of greenish fine-grained breccias with polymictic composition that excludes the Lower Triassic age (Pl. XVI, Fig. 1). They comprise clasts of radiolarites and other silicites, various types of limestones and volcanics. Among the limestone clasts, shallow and deep-water types are present; the fact, that some of them are metamorphosed and some are not, is noteworthy. It indicates a pre-Jurassic or Jurassic metamorphism in this area. In some of them, crinoidal ossicles and foraminifers are observable. Clasts of albitized rocks are also frequent (Pl. XIII, Fig. 4).

The Jurassic age of the shales and breccias is indicated by the belemnite rostra (Pl. XV, Fig. 1-4). They were found in greenish shales and breccias (diamictites) with limestone clasts, occurring at the uppermost part of the rocks at Margecany quarry, among the Middle Triassic red radiolarites and basalts. Though indeterminable, some belemnites were also found in thin sections from the rocks of other sites. Besides the belemnite rostra, some other fauna is also visible in the thin sections. There are frequent crinoidal ossicles and fragments of bivalve shells (Pl.XIII, Fig.3); rarely also some juvenile ammonoid tests were observed. The breccia itself is mainly composed of lithoclasts of grey, rarely reddish limestones and numerous clasts of volcanics (mostly with intersertal textures). The basinal filamentous and filament-radiolarian microfacies are dominant in the limestones (Pl. XIV, Fig. 1, 3, 4). According to Ištvan (1984) such limestones are of Carnian age. Besides the deep-water facies, some shallow-water ones also occur (pelsparites - Pl.XIII, Fig. 2, Pl. XIV, Fig. 2); they probably belong to Middle Triassic. Rarely also some clasts of endostratic breccias (Pl.XIII, Fig. 1) and some mica schists with garnet (Pl. XV, Fig. 5) were also found in the breccias. The margins of the limestone lithoclasts are, generally, replaced by authigenic plagioclases. The matrix of the breccia is formed by calcareous claystone with some detrital quartz grains.

Another indication of the Jurassic age of the shales is provided by the occurrence of radiolarite with poorly preserved Jurassic radiolarians (Kozur & Mock, 1995) forming a thin (4-5 cm) layer in the laminated grey shales in the forested ground above the large Margecany quarry.

The next type of the Jurassic shales are black calcareous and non-calcareous claystones observable at Kurtova skala Hill (formerly interpreted as Reigraben Shales by Gaál, 1984) and at Mačací vrch Hill (448.5 m) S of Jaklovce. As a rule, they occur together with dark fine-grained sandstones. In an excavation at the railway viaduct near Jaklovce, grey to black rocks of lyditic character were uncovered. The surrounding well exposed rocks, formerly also regarded as Lower Triassic, are phyllite-like slates, sandy shales with detrital muscovite

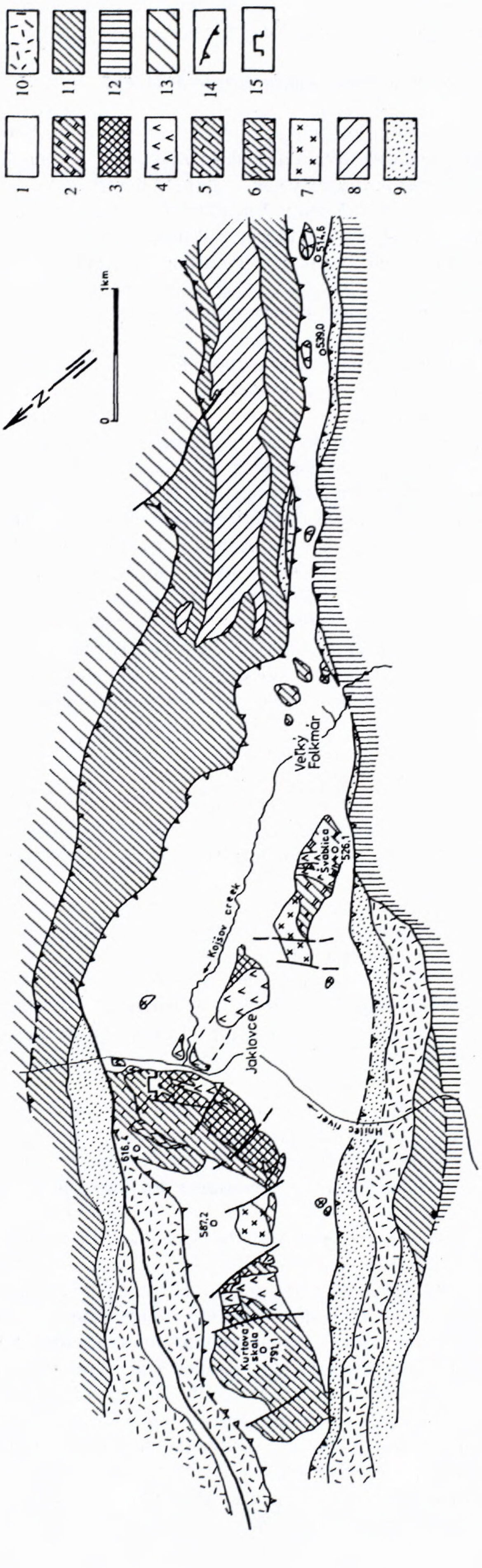


Fig.5 Geological scheme of the area of Jaklovce and Veľký Folkmár villages (according to Kamenický, 1957, Gaál, 1984 and Polák et al., 1996 modified).

MELIATICUM: 1 – matrix of melange-calcareous shales, breccias with ?blocks of Early Triassic sediments, 2 – gray platy limestones with cherts (Carnian-Norian), 3 – siliceous shales, limestones and radiolarites (Illyr-Ladinian), 4 – basaltic rocks, volc. breccias (Middle Triassic, 5 – light massive crystalline Honce limestones (Pelson), 6 – gray and yellow dolomites (Anisian), 7 – serpentinites (?Triassic);

GEMERICUM: 8 – Črmel group - metabasalts, tuffs with shale intercalations (Early Carboniferous), 9 – Krompachy group, Knola formation - metaconglomerates (Early Permian), 10 – Krompachy group, Petrova hora formation - rhyolites, dacites, volcanoclastics (Early Permian), 11 – Dobšiná group, Hámor formation - clastic metasediments (Carboniferous), 12 – Rakovec group - phyllites metavolcanics (Devonian-Carboniferous);

VEPORICUM: 13 – crystalline rocks and sediments of Čierna hora Mts., 14 – thrust lines, 15 – Margecany quarry and lenses of pale limestones. The latter may represent tectonically deformed olistoliths. Along a path from the viaduct toward the local railway station in Jaklovce, a meter sized dolomite olistolith crops out. The dolomite olistoliths are conspicuous and interesting since they are not influenced by a pressure metamorphism. Such phenomana are observable at several sites.

The melange sequence includes clastic sediments of the Early Triassic age (identified by fossils). Kozur & Mock (1995) consider these rocks as blocks in the melange. As the area is poorly exposed (outcrops are very small and sparse) it is difficult to differentiate rocks of the Jurassic matrix from the lithologically similar Early Triassic clastics. Therefore they are not separated on the sketch (Fig.5).

Important components of the Jurassic sequence are olistoliths. The most widespread are pale recrystallized shallow-water Anisian Honce limestones and dolomites. These limestones form clasts of millimetre size to megaolistoliths. The largest Meliatic olistoliths are the blocks of shallow-water Anisian limestones at Kurtova skala Hill and at the 616.4 m elevation point north of Jaklovce. Another megaolistolith, represented by pelagic cherty limestones with Norian conodonts, occurs south of Jaklovce, between Švablica and the 525.1 m elevation point (the map of Gaál in Mahel', 1986, p.138).

The limestone olistoliths, mainly of smaller size, are strongly deformed in the shales; in the past they were erroneously considered to be primary lenses or layers of the limestones in the shale formation. However, their olistolith character is recognizable only in a few places. Some egg-shaped to discoidal olistoliths encompassed in the greenish shales are commonly found, for instance, along the upper steps of the large Margecany quarry.

Other Meliatic rocks in the vicinity of Jaklovce are in most instances just olistoliths in the Jurassic shales. For instance, the basalts, red radiolarites, serpentinites and limestones at Švablica Hill are encompassed in shales, likely of the Jurassic age. A similar situation, with chaotically arranged blocks of various Anisian pale marbles (Honce limestones), Ladinian red radiolarites, Illyrian pelagic Žarnov limestones and basalts, is observable in the large Margecany quarry. In some places, the grey and greenish Jurassic shales form layers just several centimetres thick; in other places, the olistoliths are fully encompassed in the shales.

Bodies of basalts alternating with sediments are noteworthy. The largest such block is situated at the NE part of Jaklovce, at the road going towards Hnilec river. At an about 100 m-long outcrop, rocks of several basalt outflows separated by thin layers of red siliceous shales and radiolarites are observable (Jaklovce Formation sensu Kozur & Mock, 1985, p. 231). These deep-water sediments free of $CaCO_3$ contain an ubiquitous admixture of very fine detrital muscovite. Similar basalts and red deep-water sediments with submarine haematite (specularite) mineralization occur in the large Margecany quarry (Pl. XIV, Fig. 5, 6, Pl. XVI, Fig. 3).

The serpentinite blocks are difficult to rank stratigraphically. Their possible (Middle) Triassic age appear logical, since this time represented the period of the highest spreading rate of the meliatic oceanic floor.

D. Meliatic occurrences East of Jaklovce

In the Geological map of the eastern part of the Slovenské Rudohorie Mts. (Bajaník et al., 1984), a continuous narrow strip of the Lower Triassic is drawn, from Krompachy almost to Košice. According to the explanation, they are sandy shales, sandstones and limestones of the Lower Triassic, with locally preserved tiny remnants of Middle Triassic limestones. According to previous opinions, they represent part of the North Gemeric syncline, that is very narrow and reduced in its eastern segment. Permian and Triassic rocks, according to this opinion, lie directly on the Gemericum. There is no doubt that in this zone the Permian and Lower Triassic rocks really occur. The Early Triassic age was also proved by the presence of foraminifers from bedded limestones alternating with calcareous shales east of the village Jaklovce (Ištvan, 1984). However, for a long time it is known that in this narrow belt SE of Jaklovce, some diabase and serpentinite bodies are located (Kamenický, 1957), that do not fit into the Permian-Lower Triassic rock environment. We have studied some occurences that represent tiny but well exposed Meliatic remnants. Herein, just three of them will be mentioned.

In Veľký Folkmár village (Fig. 5), a serpentinite body occurs, surrounded by dark shales and fine-grained sandstones. It is best seen behind the house No.45 and along a field road going past this house. According to the present knowledge of the Meliaticum, the shales appear to be of Jurassic age. An even better example occurs behind the house No.41, where a dark shale complex outcrops. It encompasses a big block (olistolith) of pale laminated, likely shallow-water Anisian limestone. In other parts of the outcrop, numerous lenses of grey limestones occur that probably represent slightly tectonized olistoliths. An olistolith of yellowish dolomite was, however, not affected by any deformation and possess its original isometric shape. Despite of the lack of paleontological proves there is no question about the Jurassic age of the olistostrome.

Good outcrops of the Lower Triassic clastics and bedded limestones also occur at various places in Veľký Folkmár. They are, however, overlain by rauhwackes and pale recrystallized limestones macroscopically identical with Anisian limestones for example at Kurtova skala Hill.

Another occurrence of the Meliatic Unit is situated north of the road between Veľký Folkmár and Košice, near the 539 m elevation point. It is a small hill formed by black aphanitic basalts, belonging to one of the main Meliatic components. Some xenoliths of crystalline limestones indicate that the basalts had flowed to the limestone environment (Pl. XVI, Fig. 2). Other rocks, present only in debris, are greenish non-calcareous shales, greenish and light grey sandy shales, various types of sandstones and greywackes. All these rocks have a fine detrital muscovitic admixture. Also in this case, the Jurassic age of the rocks cannot be excluded.

The third Meliatic occurrence in this area is one of the most instructive outcrops of the Western Carpathians. It is a small abandoned quarry above the road between Veľký Folkmár and Košice, about 2 km west of Košické Hámre, below the 514.6 elevation point.

In the quarry wall, there is an olistostrome formation of undoubted Jurassic age. The matrix rock is greenish shales, comprising various rock components of different size and age. The whole complex is intensively deformed, even into very thin lenses. The parts consisting of numerous limestone olistoliths of similar size resemble metamorphosed nodular limestone. There are also larger blocks of pale wax-like shallow-marine limestones (originally Steinalm Limestone), various types of cherty and red limestones, containing extremely deformed and indeterminable conodonts, that indicate, however, their Triassic age. Furthermore, there are olistoliths of red radiolarites (likely of Ladinian age) and conspicuous undeformed dolomite clasts. Much of the quarry exposes greyish to black basalts overlying the sediments. They may also be a big olistolith body. The surrounding country is, however, mostly covered, further details are not observable.

The linear arrangement of the newly discovered Meliatic occurrences, as well as their intensive ductile deformation, suggest that they represent a tectonic line, along which the Meliatic components were uplifted and incorporated into the surrounding Permian and Lower Triassic rocks. This zone deserves a special structural-geological investigation.

Some Meliatic occurrences were also reported west and north of Kurtova skala Hill; they were, however, not studied by us.

E. Basic volcanic rocks of a wider surrounding of Jaklovce

1. Previous investigations

In vicinity of the Jaklovce village, numerous small bodies of basic and ultrabasic rocks occur. Field observations (e.g. in the upper part of a large quarry between Margecany and Jaklovce) confirmed, apart from older opinions (e.g. Kamenický, 1957), that they do not form continuous bodies but blocks tectonically involved into Jurassic shaly melange. No pattern was discerned in their spatial distribution, stratigraphy and thickness.

The fundamental petrological investigation of these basic rocks was carried out by Kamenický (1957) and later by Hovorka & Spišiak (1988). New views on the problematics of the studied area and new possibilities of geochemical interpretations, however, require a new treatment or at least a revision of the observations known so far. The basic rocks were affected by an oceanic floor metamorphism (chiefly spilitization in this case) and are strongly fractured and weathered which makes the geochemical and detail petrological sampling difficult.

2. Localities

In the wider surroundings of Jaklovce basic rocks occur in three areas. In some instances it is not clear whether they represent separated or continuous bodies. Taking into account this fact, the samples can be attributed (approximately) to the following larger bodies (from N):

a/. Near Kurtova skala hill and the large Margecany quarry.

b/. Near Švablica and the local manor-house.

c/. Between the Veľký Folkmár and Košické Hámre villages.

a/. Two bodies of basic rocks are situated on the SE slope of the Kurtova skala and around the Gottestal Valley; one body is in the higher parts of a small quarry in the Gottestal Valley, close to (SW of) the railway station, at the railway cut to the lime factory and on the slope above it and with some exposures also in the higher parts of the large quarry, which is probably an independent body.

b/. Another outcrop is in the village, roughly SE of the railway viaduct. On a flat hill locally called Švablica, W of the road to Folkmár, just one large body was found. The second body was mapped by Gaál (1984) as basalt but later it was seen to be a serpentinite body.

c/. The third cluster of outcrops lies along the road to Veľký Folkmár and further to Košické Hámre. Several bodies of basic rocks occur here, Veršek, Harbky, Dubov Harbek (Kamenický, 1957), but only two of them were verified by us. These are on the NE slope of the 539.0 m elevation point and close to it, in a small abandoned quarry above the road.

The literature on such occurences is difficult to work with in past because of inadequate location data and in part because local names changed.

3. Petrology of the basites

The basic rocks of the Jaklovce area represent a petrologicaly relatively homogenous group, with predominance of fine-grained types, ranging from hyaline - arborescent - intersertal - ophitic, to doleritic basalts. All of them are more or less spilitized, resulting mainly in the formation of albite, chlorite, epidote and leucoxenized Ti-minerals, at the expense of original magmatic paragenesis: basic plagioclase, volcanic glass, clinopyroxene, ilmenite and magnetite. The degree of the alteration is, of course, related also to the rock texture. The finer-grained the rock is, the more it is inclined to be altered. Hence in the coarser-grained rocks numerous relics of clinopyroxenes, important for genetic interpretation, are preserved. Therefore, the "classification" of the basalts based on the structural types is the most convenient. Such division appeared follows Kamenický (l.c.); herein, his findings will be adopted and augmented with some new data. Geochemical investigations substantiate that this approach was correct.

a.) **Medium to fine-grained metabasalts with ophitic to intersertal texture** represent the most widespread group. They occur at the Švablica Hill, in the railway cut, in the higher parts of the large quarry and also in the old quarry at Košické Hámre. Macroscopically, they are dark grey to greenish. At present they comprise an association of acicular to prismatic plagioclase of An_{32-38} (andesine) composition (approximately andesine), epidote, chlorite, clinozoisite and brownish cloudy product (probably leucoxene) after ilmenite. Other secondary minerals are calcite, limonite and pyrite. Intergranular spaces among the plagioclase needles are filled (in more fresh ophitic types) with relic clinopyroxene, compositionally close to the diopsidic augite. In finer-grained types, the vitreous mass altered into chlorite and epidote aggregates is present. Magnetite represents also a widespread accesoric component. This type is characteristic for the doleritic, ophitic and intersertal metabasalts.

b.) **Diabase porphyries with porphyric texture** have been described from two presently lost sites Dubov Harbek and Harbky at the Veľký Folkmár village Kamenický (l.c.). The samples from the railway cut in Jaklovce also belonged to this type. A difference with respect to the previous type is in the rare presence of the plagioclase phenocrysts (also with an An_{32-38} composition). They form subhedral, frequently twinned plates. Phenocrysts can occur in the texture in several varieties - intersertal, microdiabase, spilitic and blastoophitic texture.

c.) **Fine-grained basalts with arborescent textures** described Kamenický (l.c.) namely from the aforementioned "lost" localities of Harbky and Dubov Harbek. According to his original description, the rocks were formed of fan-like aggregates of thin, tiny needles of plagioclase, uralitized pyroxene and a vitreous mass in their intergranular spaces, with abundant chlorite (penninite) and lesser amount of titanite and epidote-zoisite minerals.

d.) **Aphanitic basalts** were described by Kamenický (l.c.) from another "lost" occurrence, Veršek at Veľký Folkmár. From our samples, some components of the volcanic breccias from a little quarry in the Trnkový potok valley near Košické Hámre can be assigned to this type. Macroscopically they are massive dark green rocks with hyaline and/or arborescent texture. About 60-70% of the rock consists of volcanic glass, that may be changed into fine-grained aggregates of chlorite. Clinopyroxene relics are rare and altered to chlorite-epidote aggregates. The plagioclases form irregularly dispersed tiny needles of the oligoclase-andesinic composition. Generally, the rocks are penetrated by a dense network of veinlets filled by albitic plagioclase, calcite and in places by actinolite.

e.) **Massive hyalodiabases with hyaline texture** are known again from the localities of Veršek, Harbky and Dubov Harbek (Kamenický, l.c.). Some components of the volcanic breccias are attributed to this type. These rocks are composed almost exclusively of volcanic glass (80-95%). Some tiny plagioclase needles are dispersed in this mass. Further primary components of the basites are fine pigment of the dispersed ilmenite and magnetite grains. The dense veinlet network is filled by epidote, chlorite and calcite.

f.) **Plagioclasites with intersertal structure** were not present in our samples. Kamenický (l.c.) mentioned them from the localities of Harbky and Dubov Harbek. He distinguished them by their higher percentage of plagioclases (up to 80%) with respect to the previous types. The plagioclase of these rocks is fine prismatic and tabular; the rest of the rock consists of volcanic glass and the products of its alteration (rarely also tiny clinopyroxene crystals) to chlorite-epidote aggregates.

Two other types can be added to the classical division of Kamenický (l.c.):

g.) **Coarse-grained metabasalt ("plagioclasite") with ophitic structure** was found in one sample from the abandoned quarry near Košické Hámre. It differs from the other ophitic basalts by its high content of massive plagioclase crystals (up to 80%); from the type f it differs only structurally. Clinopyroxene remnants are rare; the clinopyroxene crystals usually are altered to chlorite. Actinolite needles in xenomorphic chlorite grains, are a peculiarity.

h.) **Volcanic breccia** was found on the SE ridge of the 539.0 m elevation point between Košické Hámre and Veľký Folkmár and at the small abandoned quarry near Košické Hámre. The rock structure is brecciated, with matrix composed of volcanic glass, in places with relatively coarse-grained epidote aggregates. Irregularly dispersed basitic clasts of various grain-size are present, dominated by the fine-grained, hyaline, arborescent or intersertal types. The matrix and the clasts are pervasively spilitized; they represent a mixture of chlorite, brownish (likely titanium) pigment and calcite. The individual components, unfortunately, were not sufficient for geochemical sampling.

The named types represent various members of one volcanic series. A possible spatial shortening among the different basalt types results apparently from the tectonic reworking of the melange. The localities at Košické Hámre, Veľký Folkmár (and at the "lost" localities Veršek, Harbky and Dubov Harbek) are dominated by the vitreous and breccious types, whereas the Švablica and Jaklovce localities (at various places - in the large quarry and in the vicinity of Kurtova skala Hill) are characterized by a predominance of the intersertal and ophitic types. Note, that the lower oceanic crust, i.e. the major part of the ophiolite sequence (gabbros, cumulate complex etc.), is missing. The serpentinites in this area are evidently tectonically introduced into the melange structure, without genetic connection to the basalts.

The basaltic rocks from the Jaklovce area are considered to be the products of submarine volcanism with a dominant lava character. Although the pillow-lava structures have not been found, some parts of former lava flows can be determined. The vitreous rocks and volcanic breccias are the flow margins, the grain-size coarsens towards the center of the flow and changes through the arborescent and intersertal types to the ophitic types. The doleritic types indicate an origin of increased depths or in the center of the lava flow; some of them might even have come from a feeder dyke complex.

4. Mineralogy and geochemistry

Several methods have been used for deciphering the genetic relationship of the Jaklovce metabasalts, including microprobe analyses of the relic clinopyroxenes, silicate analyses and rare element analyses (detailed geochemical characteristics are being prepared).

Major element distribution and rare elements indicate association of the metabasalts to the oceanic tholeiites, in some cases with slight alkaline trend, that reflect ocean-floor alteration processes.

Based on the minor element distributions, the basalts are most similar to N-MORB (normal mid- ocean ridge basalts) with tendency to CAB (calc-alkaline basalts), which is characteristic for back-arc basin (Fig. 6).

The chondrite normalized patterns of REE show two groups: differentiated and non-differentiated types (Fig. 7)

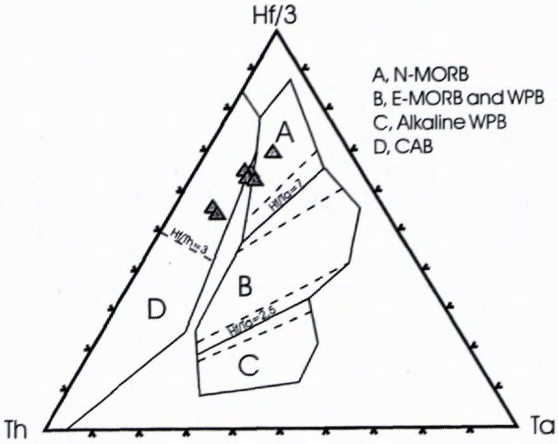


Fig. 6 Hf/3-Th-Ta discrimination diagram of the Jaklovce metabasalts (after Wood, 1980)

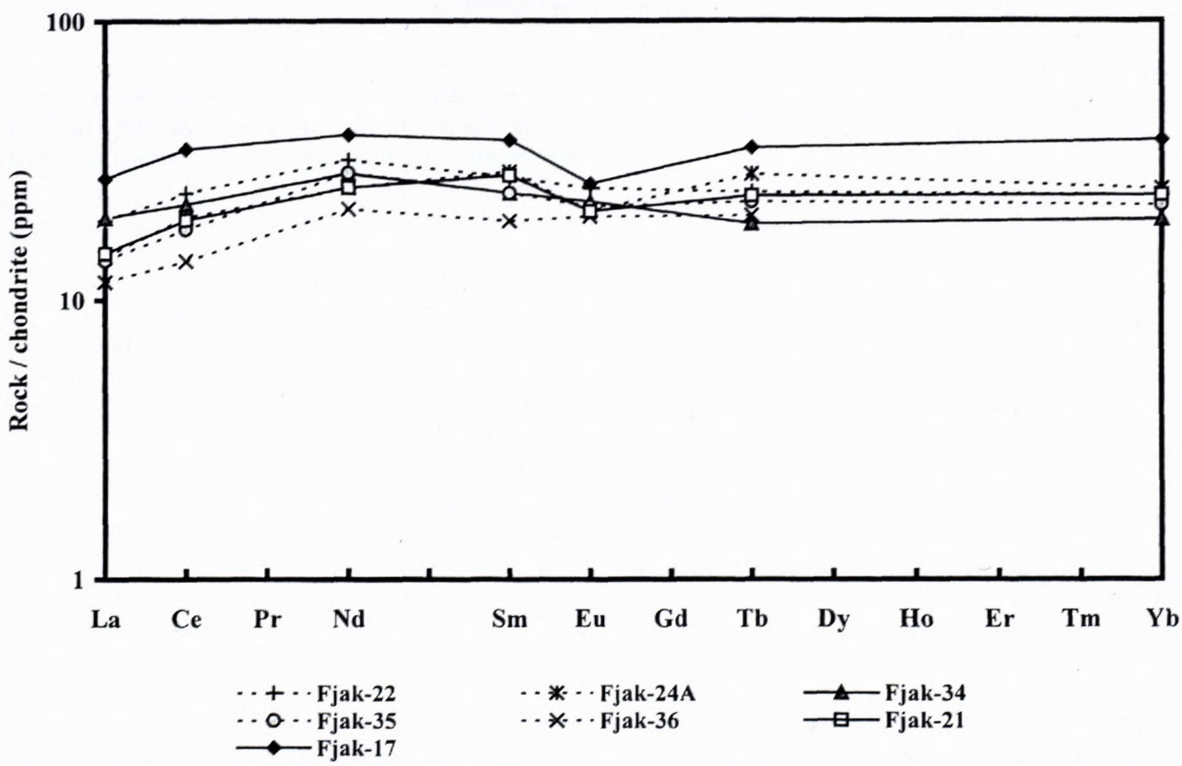


Fig. 7 Chondrite normalized patterns of REE for the Jaklovce metabasalts (normalization after Evensen & al., 1978).

F. Heavy mineral analysis of the Meliatic sediments from the Meliata and Jaklovce areas

Ten positive samples (containing enough sandy admixture) were analyzed from the Meliatic siliciclastic rocks (Tab. 3, Fig. 5, 6). They come not only from the Meliata area but also from the large quarry near Margecany and from the Florianikogel, the first Meliatic locality discovered in Austria (Mandl & Ondrejičková, 1992).

The locations of the sample sites are as follows:

Margecany - large quarry - sample represents a sandstone of uncertain stratigraphic position, found in the area of the Meliatic occurrences between Jaklovce and Margecany.

Meliata - above the southern end of the type profile - two samples of sandstones were taken from the slope debris.

Meliata - quartzites N of the type profile - two samples were taken from the quartzite blocks, cropping out on the slope upstream, behind the river curve. The quartzites are of uncertain stratigraphic and tectonic position.

Meliata - house No.72 - two samples were taken from the green siltstones and silty claystones in the outcrop behind the stable at this house.

Tab. 3 Percentual ratios of the translucent heavy minerals from the Meliata Unit.

	Gr	Zr	Ru	Tu	Ap	Am	Ti	St	Bar	Sp	Di
Margecany - large quarry	1	23	11	52	12	0	0	0	0	0	0
Meliata-end of the profile 1	1	35	9	42	1	0	1	0	10	0	0
Meliata- quartzites behind the type profile1	1	26	3	64	6	0	0	0	0	0	0
Meliata- quartzites behind the type profile 2	0	43	10	24	4	4	1	0	13	0	0
Meliata-end of the profile 2	9	39	13	38	0	0	0	*	*	0	0
	Gr	Zr	Ru	Tu	Ap	Am	Ti	St	Bar	Sp	Di
Meliata-house n.72/2	31	2	1	1	10	4	0	0	40	10	0
Meliata-house n.72/1	46	1	0	0	9	1	0	0	42	1	0
Meliata-100m above the protestant church.	29	1	1	**	8	1	1	0	57	0	1
Meliata - at the protestant church	43	3	3	0	10	0	0	0	40	0	0
Florianikogel	27	10	5	6	28	2	0	0	22	0	0

Explanations: Gr - garnet, Zr - zircon, Ru - rutile, Tu - tourmaline, Am - amphibole, Ap - apatite, Ti - titanite, St - staurolite, Cr - chromium spinels, Ba - baryte, + - content less than 1%

Meliata - the protestant church - two greenish siltstone samples were taken from the temporary pipeline excavations around the church.

Florianikogel, Austria - a sandstone sample was taken from the first Meliatic locality discovered in the eastern Alps.

Possibilities of comparison of the Meliatic samples with other units are restricted since most of the samples lacks precise stratigraphic position. Four analysed samples from the siltstone layers in greenish claystones were dated as Middle to Late Jurassic.

The data obtained by counting of the translucent heavy mineral grains are grouped by their composition into two different groups. The first group includes the sandstone and quartzite samples of uncertain stratigraphic position within the Meliatic Unit. The uncertainity was caused by the complex geological structure resulting from subduction and collision tectonics that generally makes it difficult to distinguish between normal beds and olistoliths of tectonicly involved blocks. This group is characterized by the presence of the assemblage of tourmaline, zircon and rutile, which is the most resistant group of heavy minerals. It indicates that either its source was some older siliciclastic rocks, or it originated after deposition by an intrastratal dissolution of less stable minerals. Such an assemblage is typical for the Jurassic sediments all around the Central and Inner Western Carpathians. The second group is represented by the siltstone samples, coming from the greenish non-calcareous claystones and by the sandstone sample from Florianikogel locality. This group contains mainly garnet and abundant apatite, baryte (likely authigenic), sparse chromium-spinel grains are also present. In the Jurassic of the Western Carpathians, the higher concentrations of detrital garnet are typical only for the Outer Carpathians (Pieniny Klippen Belt, Flysch Belt) and foreland units (autochthonous Jurassic sediments covering the slopes of the Bohemian Massif). However, a comparison of these units with the Meliata Unit only on the basis of heavy minerals remains premature.

G. Conclusions

The melange of the two studied areas of the Meliata units are mutually similar, yet in some details they differ. In the Meliata village area, the Meliata Unit contains blocks (olistoliths) of limestones, radiolarites, volcanics and clastics. These were transported to the deep-water environment by turbidity currents. The olistoliths are stratigraphically variable; in the published papers of Kozur & Mock (1980), Straka (1986), Kozur (1991), Kozur et al. (1996) there is a lot of age data of limestones, cherty limestones and radiolarites from the Meliata tectonic half-window. From these data augmented by our new information it can be stressed that the breccias at this area contain blocks of Lower to Middle Triassic limestones, Ladinian siliceous limestones and radiolarites, olistostrome blocks with Carnian and Norian limestone lithoclasts, blocks of likely Lower Jurassic limestones and Middle Bathonian to Lower Oxfordian radiolarite olistoliths (in places occurring as continuous layers). The latter form the morphologically conspicuous elevations of Hámor (335m) and Guba (322m) hills. Additionally, some olistoliths of basic volcanics, blocks of paleorhyolite and arkosic sandstone are sparsely present at the Meliata village. The latter two blocks are presumably of Paleozoic age.

The olistoliths of Mesozoic rocks represent various stages of the Meliatic evolution. The dark-grey Lower Triassic, light-grey (predominantly intensively metamorphosed) Lower Anisian shallow-water Honce Limestone, paleorhyolite and arkosic sandstone document the pre-rift stage. The start of riftogenesis is characterized by basinal red Žarnov Limestone with radiolarians, filaments and conodonts. These cover the Lower Anisian limestones, frequently forming fissure fillings in fractured bottom. The sedimentation of pelagic limestones, radiolarites and cherty limestones continued during Ladinian and Late Triassic, also. According to Kozur (1991) and our own observations a change in the sedimentation character took place during the Late Triassic. At that time the sedimentation of allodapic limestones and limestone breccias began. During the Early Jurassic, clayey calcareous shales with limestone layers and lithoclasts became dominant. The Middle Jurassic period was characterized by the start of matrix supported breccias (olistostromes) as a result of continental margin tectonics. The process of olistostrome formation finished in the Early Oxfordian (or later), since the youngest known radiolarian assemblage from radiolarite (layer 103, Fig. 4) is of Late Callovian-Early Oxfordian age (Kozur et al., 1996). The melange matrix is

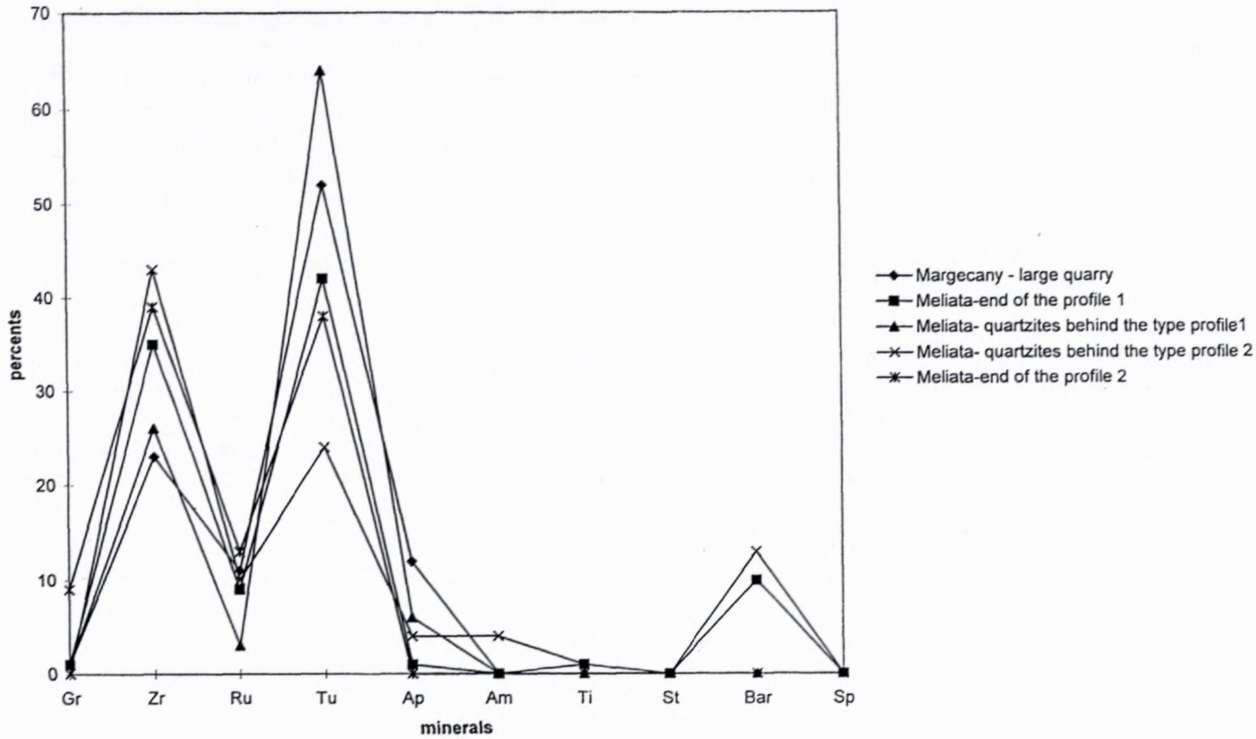


Fig. 8 Diagram displaying percentual contents of the translucent heavy minerals from the sandstones and quartzites of the Meliata Unit (group No.1).

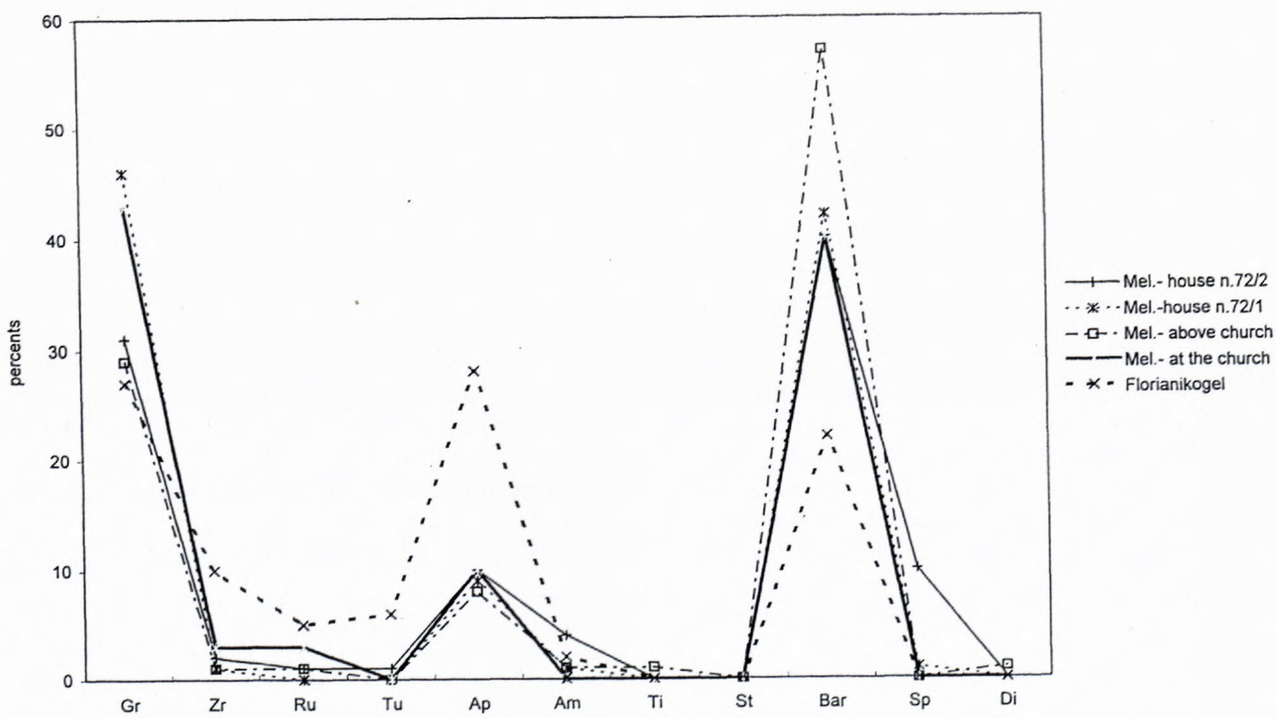


Fig. 9 Diagram displaying percentual contents of the translucent heavy minerals from the siltstone layers in the Middle Jurassic greenish claystones and the sandstone from the Florianikogel locality (group No.2).

represented by clastic development - clayey shales, siltstones, sandstones and rare breccias. On the left bank of Muráň river (Fig. 4) there is the grey radiolarite layer and laminae of presumably chloritized tuffites. According to Kozur (1991) the volcanic activity finished in the Early Cordevolian. The entire rock sequence was then anchimetamorphosed.

Microscopic analysis of the sandstones and breccias provided some information on the source of clastics. These psammites and psephites consist mainly of sedimentary rocks (predominantly limestones) and volcanic rocks. The limestone lithoclasts occur either as light-grey marbles or as pale non-metamorphosed shallow-water, most likely Triassic limestones. Similarly, the marbles and weakly metamorphosed limestones with the preserved original structures and microfossils also occur among carbonate olistoliths in the melange. A difference also is evident between the metamorphism of the Jurassic matrix and marbles. According to illite crystallinity (Šucha, pers. comm.), the Jurassic shales are just weakly anchimetamorphosed, whereas the conodonts from the marbles were strongly deformed and corroded (CAI 6). This indicates that the source area includes both, metamorphosed and unmetamorphosed limestone terranes, some even of the same age.

The lithoclasts of volcanics (basalts) represent predominantly fragments of submarine lava flows (glass to "doleritic" textures).

The melange in the Jaklovce area consists of lithologically, stratigraphically and dimensionally variable blocks. The pre-rift stage is also represented by Honce Limestone (its age was, however, not yet proven in this area), paleorhyolites and locally probably also by Lower Triassic clastics. The weakly metamorphosed Honce Limestone is overlain by reddish-grey to red Žarnov Limestone. According to Nižňanský (1982) and Ištvan (1984), it is of Pelsonian-Illyrian? age. As in the Meliata area, they commonly form fissure fillings related to the synrift stage of the Meliatic evolution.

NE of Veľký Folkmár village (Fig. 5) there is a megablock displaying a contact between weakly metamorphosed limestone (presumably Honce Limestone) with so called Jaklovce paleobasalts of the Švablica Formation. This indicates that before, or synchronously with, the sedimentation of the Žarnov Limestone, volcanic activity occurred locally within the newly formed rift structure.

The red limestones are overlain by a rock sequence referred to by Gaál (1984) as the diabase-shale-silicite complex. Its inferred age is Illyrian to Ladinian. In this complex, the deep-water siliceous shales with radiolarite layers are dominant. Their colour is chiefly greyish-red to red. Some irregular metabasalt bodies occur in the shales also. According to the minor element distribution, they are similar to marginal and back-arc basin basalts.

As in the Meliata area, carbonate sedimentation of conodont-bearing grey cherty limestones (now preserved as blocks) occurred in the Late Triassic (Cordevolian-Julian-?Norian). Unlike the Meliata area, no olistoliths of Jurassic sediments (radiolarites) were found in the Jaklovce area. This northern area of Meliatic Unit is typical by serpentinite olistolith occurrences, namely at Švablica hill. Blocks of paleorhyolites and keratophyres are scarce.

Unlike at Meliata, the matrix of the melange in this "Folkmar Suture Zone" (Kozur & Mock, 1995) is chiefly formed by grey to greyish-green calcareous claystones; siltstones and sandstones are less frequent. In the Jurassic sedimentary complex, breccias, dominated by lithoclasts of Triassic basinal to shallow-water limestones, occur rarely. Locally also belemnite rostra fragments are found in the breccias, directly indicating their Jurassic age. Kozur & Mock (1995) determined the Middle Jurassic (likely Bathonian) radiolarians in silicite intercalations in the turbiditic clastics NE of Jaklovce. The Lower Triassic sediments, locally determined by microfossils, are lithologically similar to the Jurassic clastics. Therefore, it is often difficult to discern them and to determine their mutual relationship, which is also frequently complicated by extensive Quaternary sedimentary cover. Kozur & Mock (l.c.) consider the Lower Triassic detritic sediments as blocks in the melange.

The sedimentation of the thick Jurassic shaly formation with the olistostrome bodies indicates an environment of a subduction trench. Recently, such sediments resembling an accretionary zone sequences that were studied by some of us in 1990 on the Chukotka Pacific coast. The deep-sea shales and radiolarites of the Meliatic Jurassic resemble the Chukotka sediments named by local geologists as "shukha". In the Meliaticum, however, only a few relics of an accretionary prism are preserved, which, moreover, are affected by several orogenic deformation events. Some young lateral movement along this suture, the location of which is still uncertain and disputed, surely played an important role.

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Explanations to the Plates I–XVI

Plate I

Fig. 1 Upper Jurassic claystone with irregularly developed laminae of quartz sand. Melange between the Muráň river and Hámor hill (NW of Meliata). Thin section No.22 107, magn.27x.

Fig. 2 Paleorhyolite - block in the melange NW of Meliata (see text fig.3). It contains magmatically corroded quartz, K-feldspars and devitrified glass. Thin section No.22 105, magn.8.5x.

Fig. 3 Middle Jurassic radiolarite from Hámor hill (megaolistolith). Thin section No.22 092, magn.45x.

Fig. 4 Cataclasis of a radiolarite lithoclast from the complex of Upper Jurassic clastics at the northern margin of the Meliata village. Thin section No.21 028, magn.27x.

Plate II

Detrital layers from the Meliata Unit type profile (scale=1cm).

Fig.1 Cross-section of polymictic breccia bed (one of the rare layers in the Middle Jurassic shales), representing a graded-bedded turbidite deposited from high-density turbidity current. It contains abundant rip-up clasts of the underlying clayey shales.

Fig.2 Cross-section of a laminated channel filling in the Middle Jurassic claystones. The visible grade-bedded laminae (deposit of traction carpet) are overlain by a psephitic layer. Sample of debris.

Fig.3 Polymictic breccia (grain flow deposit?) from the Middle Jurassic shale complex. The breccia comprises mainly of clasts of spilitized volcanics, limestones, pale marbles and albitized sedimentary rocks.

Fig.4 Two layers of coarse-grained sandstones to fine-grained breccias in the Middle Jurassic claystones. The lighter part of the shale between the sandstone layers was seismicly disturbed and slided along a newly formed plane, oblique to the bedding.

Plate III

Detrital material from the breccias and sandstones from the Meliata Unit type profile (see Pl. II).

Fig.1 Recrystallized calcite ooid, as a clast, in the sedimentary breccia. Thin section No.20 658, magn.46x.

Fig.2 Triassic (?) foraminifer in a biosparitic (grainstone) lithoclast from a polymictic breccia. Thin section No.20 660, magn.80x.

Fig.3 Cross-section of a bivalve shell represents one of the rare bioclasts in the breccia. The thin lithoclast is a claystone rip-up clast from the underlying bed. Thin section No.20 654, magn.46x.

Fig.4 Corroded and bored echinoderm ossicle, as a clast in the breccia. Thin section No.20 662, magn.30x.

Fig.5 Oncoid, as a clastic grain in the breccia. Thin section No.20 659, magn.40x.

Fig.6 Oosparite-grainstone of Triassic or Early Jurassic age, as a lithoclast in the breccia. Thin section No.20 654, magn.46x.

Fig.7 Pelsparite-grainstone, as a lithoclast in the breccia. Thin section No.20 662, magn.46x.

Fig.8 Pelmicrosparite with *Aeolisaccus* sp. - Triassic lithoclast in the breccia. Thin section No.20 659, magn.46x.

Plate IV

Detrital material from the breccias and sandstones from the Meliata Unit type profile (see Pl. II).

Fig.1 Lithoclast of non-recrystallized volcanic glass with amigdales. The glass contains opaque pigment; the amigdales are filled with calcite and chlorite. Plain light, thin section No.20 654, magn.27x.

Fig.2 Lithoclast of volcanic glass with deformed amigdales filled by calcite. Parallel polars, thin section No.20 654, magn.46x.

Fig.3 Lithoclast of recrystallized volcanic glass with pseudomorph of albite after a magmatic plagioclase. Crossed polars, thin section No.20 953, magn.46x.

Fig.4 Lithoclast of recrystallized volcanic glass with signs of an intersertal texture. The phenocrysts form thin laths of plagioclase. Crossed polars, thin section No.20 656, magn.30x.

Plate V

Clasts of basic volcanics in the detrital layers (see Pl. II)

Fig.1 Lithoclast of vitreous basalt with acicular crystals of plagioclase and opaque pigment. The amigdales are filled with chlorite. Crossed polars, thin section No.20 656, magn.27x.

Fig.2 Basaltic lithoclast with intersertal texture comprising the needle plagioclase crystals, glass and opaque pigment. Crossed polars, thin section No.20 657, magn.27x.

Fig.3 Lithoclast of basalt with ophitic texture, with plagioclase phenocrysts and partially also opaque pigment. Crossed polars, thin section No.20 654, magn.30x.

Fig.4 Coarse-grained basalt (dolerite?) as a lithoclast of the sedimentary breccia. Crossed polars, thin section No.20 654, magn.46x.

Plate VI

Detrital material from the breccias and sandstones from the Meliata Unit type profile (see Pl. II).

Fig.1 Lithoclast of micrite with calcitic pseudomorphs after gypsum crystals (probably Triassic) in the polymictic breccia. Thin section No.20 953, magn.30x.

Fig.2 Radiolarite lithoclast (Triassic?) in the breccia. Thin section No.20 955, magn.30x.

Fig.3 Metamorphosed limestone as a lithoclast in the breccia. Crossed polars, thin section No.20 657, magn.30x.

Fig.4 Lithoclasts of metamorphosed limestone and claystone (the rip-up clast) in the breccia. Thin section No.20 656, magn.95x.

Plate VII

Fig.1 Keratophyre as a lithoclast in the sedimentary breccia. The feldspar crystals are oval shaped with signs of spheroidal texture. The matrix among the grains is carbonate and albite (from the detrital layers as the previous plates). Thin section No.20 958, magn.95x.

Fig.2 Jurassic spotted bioturbated claystone with some quartz and chlorite grains. Outcrop at the left bank of the Muráň river (text fig. 4). Thin section No.20 524, magn.30x.

Fig.3 Pressure deformed carbonate breccia (probably Jurassic). The lithoclasts are the Carnian metamorphosed limestones. Locality - as for Fig. 2.

Fig.4 Middle Jurassic laminated clayey shale. The laminae formed by Fe-chlorite represent probably a chloritized tuffitic material related to synchronous volcanism. Locality - as for Fig. 2.

Plate VIII

Fig.1 Intrasparite - a block in the melange NW from Meliata. The foraminifers (outside the figure) indicate its Pelsonian age. Thin section No.23 101, magn.32x.

Fig.2 *Hoyanella* sp. (left) and *Cornuspira* sp. (right), from a block of Lower Triassic metamorphosed limestone. Locality - near the NE margin of Meliata (text fig.3). Thin section No.24 722, magn.62.5x.

Fig.3 Filaments and poorly preserved calcified radiolarians in a reddish-grey Pelsonian Žarnov Limestone (the age indicated by conodonts). Left bank of the Muráň river (text fig.4). Thin section No.20 793, magn.19x.

Fig.4 Lithoclast of biomicrite with filamentous microfacies (probably Carnian) in the Jurassic shales. Left side of the Muráň river valley, at the Meliata mill. Thin section No.21 050, magn.32x.

Fig.5 Lamina of detrital limestone with ostracod tests in a clayey limestone block (probably Lower Jurassic). Close to the NE margin of Meliata. Thin section No.21 060, magn.27x.

Fig.6 Resedimented radiolarians as a detritus in a Jurassic siltstone. Northern margin of the Meliata village. Thin section No.21 617, magn.86x.

Plate IX

Radiolarians from the sample M-7 (Meliata)

Fig.1 *Stylocapsa oblongula* KOCHER - 0535, magn.500x
Fig.2 *Dictyomitrella(?) kamoensis* MIZUTANI et KIDO - 0537, magn.350x
Fig.3 *Parvicingula dhimenaensis* s.l. BAUMGARTNER - 0551, magn.300x
Fig.4 *Tricolocapsa conexa* MATSUOKA - 0548, magn.380x
Fig.5 *Unuma* sp.A sensu BAUMG. et al.,1995 - 0557, magn.400x
Fig.6 *Stichocapsa robusta* Matsuoka - 0536, magn.280x
Fig.7 *Archaeodictyomitra exigua* Blome - 0555, magn.500x
Fig.8 *Transhsuum maxwelli* gr. (PESSAGNO) - 0547, magn.300x
Fig.9 *Zhamoidellum* sp. - 0549, magn.390x
Fig.10 *Stichocapsa convexa* Yao - 0530, magn.310x
Fig.11 *Williriedellum* sp. - 0532, magn.350x
Fig.12 *Eucyrtidiellum semifactum* Nagai et Mizutani - 0526, magn.550x
Fig.13 *Archaeodictyomitra primigena* Pessagno et Whalen - 0554, magn.600x

Plate X

Radiolarians from the samples M-3, M-3/3 (Meliata)

Fig.1 *Stichocapsa robusta* Matsuoka - 3,3995, magn.300x
Fig.2 *Dictyomitrella*(?) *kamoensis* Mizutani et Kido-3/3,2788, magn.300x
Fig.3 *Parvicingula dhimenaensis* s.l. Baumgartner - 3/3, 2796, magn.300x
Fig.4 *Tricolocapsa conexa* Matsuoka - 3/3, 2799, magn.400x
Fig.5 *Transhsuum maxwelli* gr.(Pessagno) - 3/3, 2810, magn.300x
Fig.6 *Transhsuum* cf. *brevicostatum* (Ožvoldová) - 3/3, 2797, magn.300x
Fig.7 *Tricolocapsa* cf.*plicarum* Yao - 3, 4047, magn.380x
Fig.8 *Stichocapsa convexa* Yao - 3/3, 2798, magn.400x
Fig.9 *Stylocapsa oblongula* Kocher - 3, 4036, magn.600x
Fig.10 *Williriedellum* sp.A sensu Matsuoka,l983 - 3, 4046, magn.450x
Fig.11 *Obesacapsula morroensis* Pessagno - 3/3, 2805, magn.175x
Fig.12 *Archaeodictyomitra* sp.- 3, 4037, magn.550x
Fig.13 *Theocapsomma* cf.*cordis* Kocher - 3, 4049, magn.500x

Plate XI

Radiolarians from the sample M-103B (Meliata)

Fig.1 *Cinguloturris carpatica* Dumitrica - 0183, magn.28Ox
Fig.2 *Eucyrtidiellum ptyctum* Riedel et Sanfilippo - 0185, magn.420x
Fig.3 *Stichocapsa robusta* Matsuoka - 0215, magn.330x
Fig.4 *Ristola altissima major* Baumgartner et De Wever - 103B, 0219, magn.175x
Fig.5 *Tricolocapsa conexa* Matsuoka - 0233, magn.390x
Fig.6 *Theocapsomma cordis* Kocher - 0225, magn.500x
Fig.7 *Stylocapsa oblongula* Kocher - 0240, magn.500x
Fig.8 *Stichocapsa convexa* Yao - 0215, magn.300x
Fig.9 *Archaeodictyomitra rigida* Pessagno - 0179, magn.350x
Fig.10 *Transhsuum brevicostatum* (Ožvoldová) - 0218, magn.300x
Fig.11 *Archaeospongoprunum imlayi* Pessagno - 0190, magn.240x
Fig.12 *Semihsuum sourdoughense* Pessagno,Blome et Hull - 0214, magn.330x
Fig.13 *Parahsuum*? sp. - 0180, magn.420x
Fig.14 *Podobursa* sp. - 0181, magn.225x

Plate XII

Radiolarians from the sample G-6 (Guba)

Fig.1 *Eucyrtidiellum ptyctum* Riedel et Sanfilippo - 2041, magn.400x
Fig.2 *Eucyrtidiellum semifactum* Nagai et Mizutani - 2700, magn.520x
Fig.3 *Parvicingula dhimenaensis* ssp.A sensu Baumgartner et al. 1995 - 2687, magn.390x
Fig.4 *Spongocapsula palmerae* Pessagno - 2688, magn.290x

Fig.5 *Unuma* sp.A sensu Baumgartner et al.1995 - 2683, magn.390x
Fig.6 *Tricolocapsa conexa* Matsuoka - 2047, magn.410x
Fig.7 *Acanthocircus suboblongus* s.l. Yao - 2684, magn.300x
Fig.8 *Unuma latusicostatus* (Aita) - 2686, magn.400x
Fig.9 *Stichocapsa* sp. E sensu Baumgartner et al.1995 - 2689, magn.320x
Fig.1O *Acanthocircus* sp.- 2039, magn.300x
Fig.11 *Eucyrtidiellum unumaense unumaense* (Yao) - 2671, magn.500x
Fig.12 *Protunuma*? *lanosus* Ožvoldová - 2667, magn.450x
Fig.13 *Stichocapsa convexa* Yao - 2049, magn.390x
Fig.14 *Angulobracchia* sp. - 2677, magn.150x

Plate XIII
Components of breccias from the area between the Margecany quarry and Kurtova skala hill.
Fig.1 Lithoclast of an older limestone breccia in the Jurassic sedimentary breccia. Thin section No.21 826, magn.30x.
Fig.2 Pressure deformed lithoclast of pelsparite-grainstone (Triassic?) in the Jurassic sedimentary breccia. Thin section No.21 825, magn.30x.
Fig.3 Lithoclast of volcanite (devitrified glass) and bivalve shell fragment in the Jurassic breccia. Thin section No.21 826, magn.30x.
Fig.4 Micrite clast with authigenic feldspar grains (left) and bioclasts in the Jurassic breccia. Thin section No.21 826, magn.30x.

Plate XIV
Components of breccias and shales from the top part of the Margecany quarry.
Fig.1 Lithoclast with filamentous microfacies (probably Upper Triassic) from carbonate breccia in the Jurassic shales. Thin section No.23 524, magn.19x.
Fig.2 Pelbiosparite lithoclast with filaments and peloids (probably Upper Triassic). Thin section No.23 533, magn.19x.
Fig.3 Biomicrite lithoclast with calcified radiolarians and rare filaments (probably Upper Triassic). Thin section No.23 525, magn.19x.
Fig.4 Biomicrite lithoclast with calcified radiolarians, filaments and a juvenile ammonoid test. Thin section No.23 524, magn.19x.
Fig.5 Radiolarite with stylolites and pressure deformed radiolarian tests. Detrital quartz grains (silt to fine-grained sand) visible on the left side of the picture. From the red shale formation at the top part of the quarry. Thin section No.21 829, magn.48x.
Fig.6 Haematite-siliceous lamina in radiolarite (for the rock see Pl.XVI, Fig.3. Thin section No.21 829, magn.48x.

Plate XV
Fig.1,2 Fragments of belemnite rostra in the Jurassic carbonate breccia. Locality - top part of the Margecany quarry (scale = 1cm).
Fig.3,4 Transverse (3) and longitudinal (4) cross-section through a deformed belemnite rostrum from the Jurassic carbonate breccia. Locality - as for Figs.1 and 2. Magn. 8x.
Fig.5 Pressure deformed lithoclast of a garnet mica-schists and an echinoderm ossicle replaced by pale grey silicate in the Jurassic carbonate breccia. Locality - the area between the Margecany quarry and Kurtova skala hill. Magn. 30x.

Plate XVI
Fig.1 Carbonate breccia from the Jurassic shale formation. Locality - the area between Margecany and Kurtova skala hill. All scales = 1cm.
Fig.2 Breccia composed of metamorphosed limestone and tuffitic material. Locality - abandoned quarry at the road brtween Košické Hámre and Veľký Folkmár.
Fig.3 Radiolarite with lensoid laminae of haematite-siliceous rock (see also Pl.XIV, Fig.6) from the Jurassic red shale formation. Locality - top part of the Margecany quarry.
Fig.4 Breccia comprising grey fine-grained silicite clasts and red siliceous matrix from the Jurassic red shale formation. Locality - top part of the Margecany quarry.

Plate I

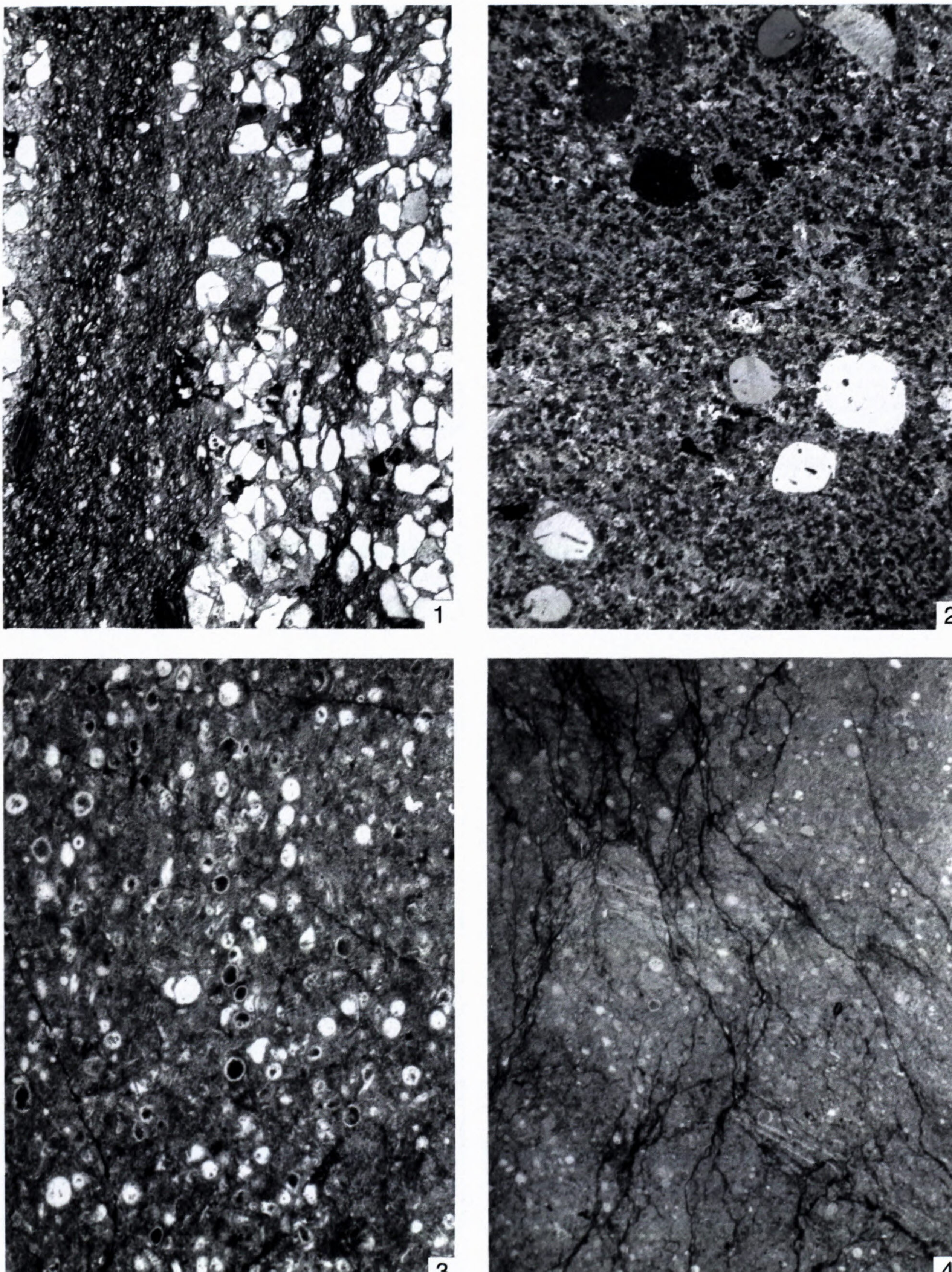
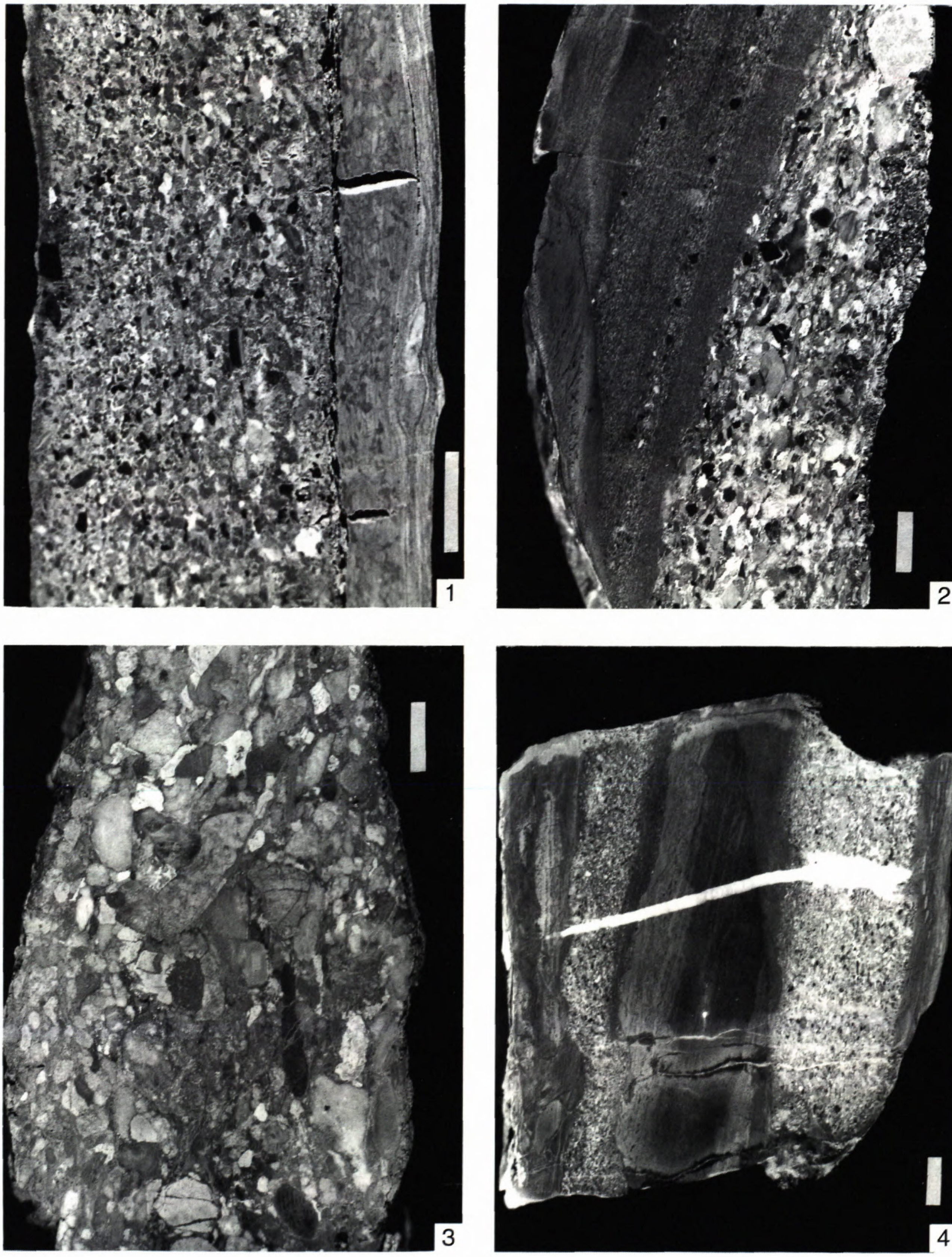


Plate II



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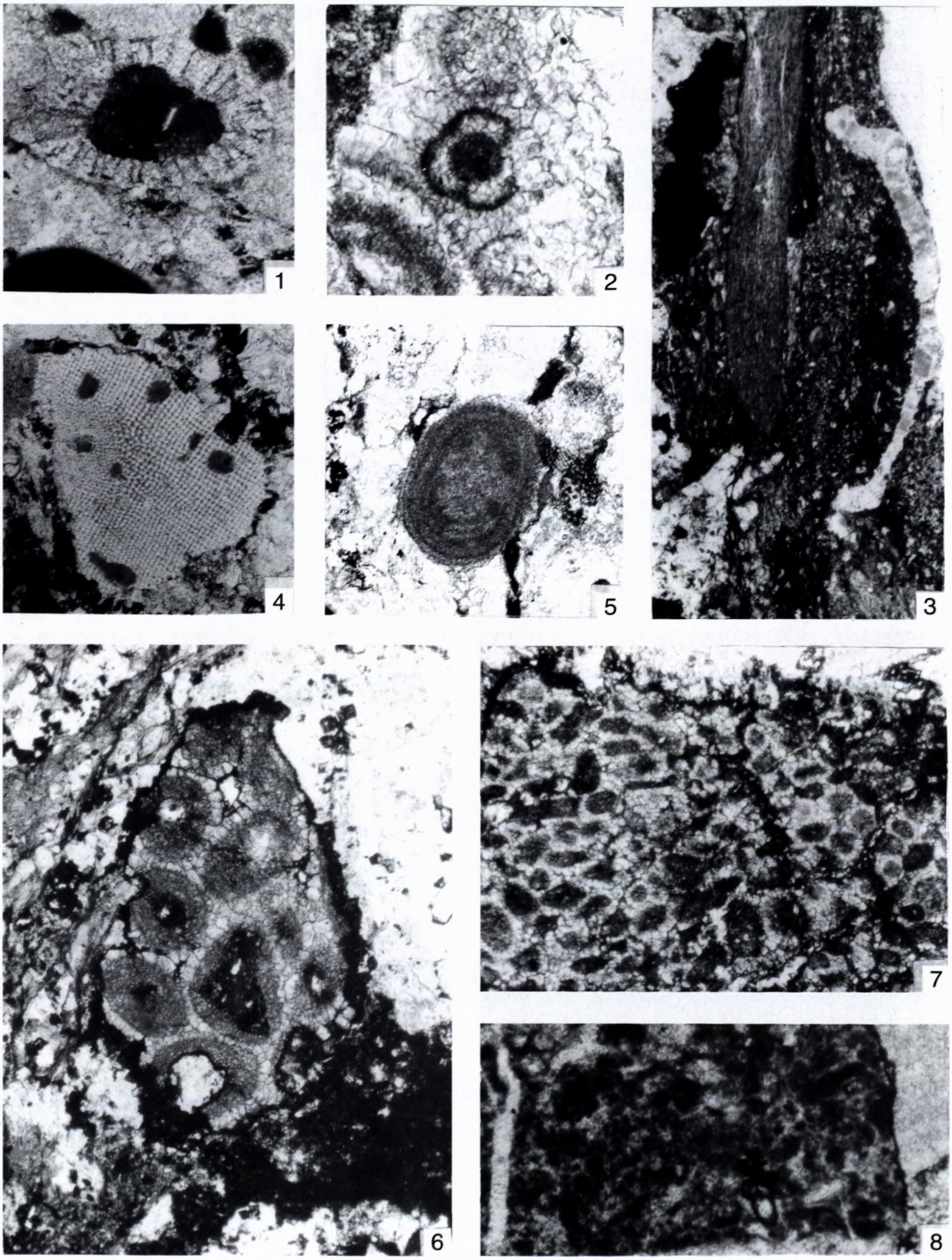

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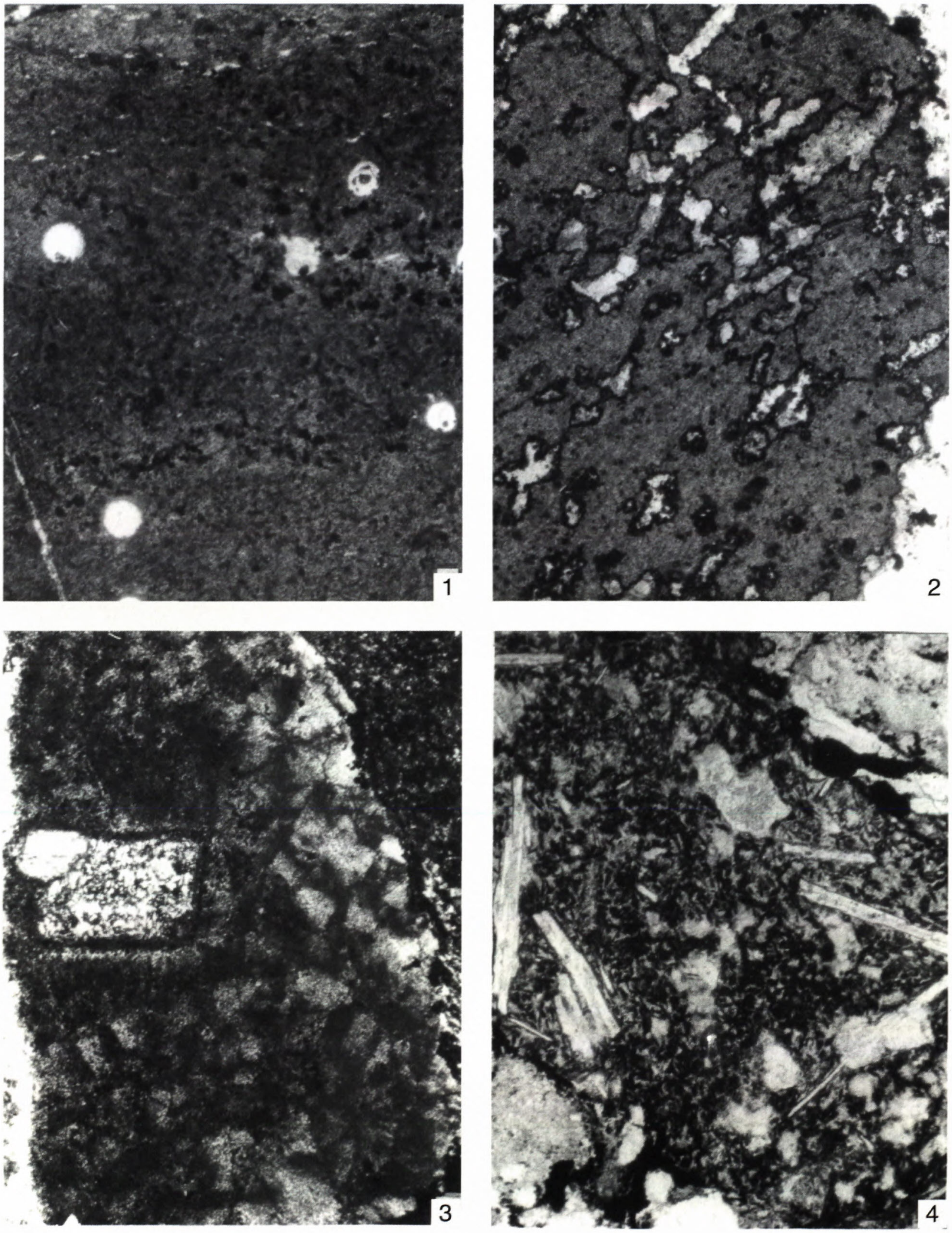

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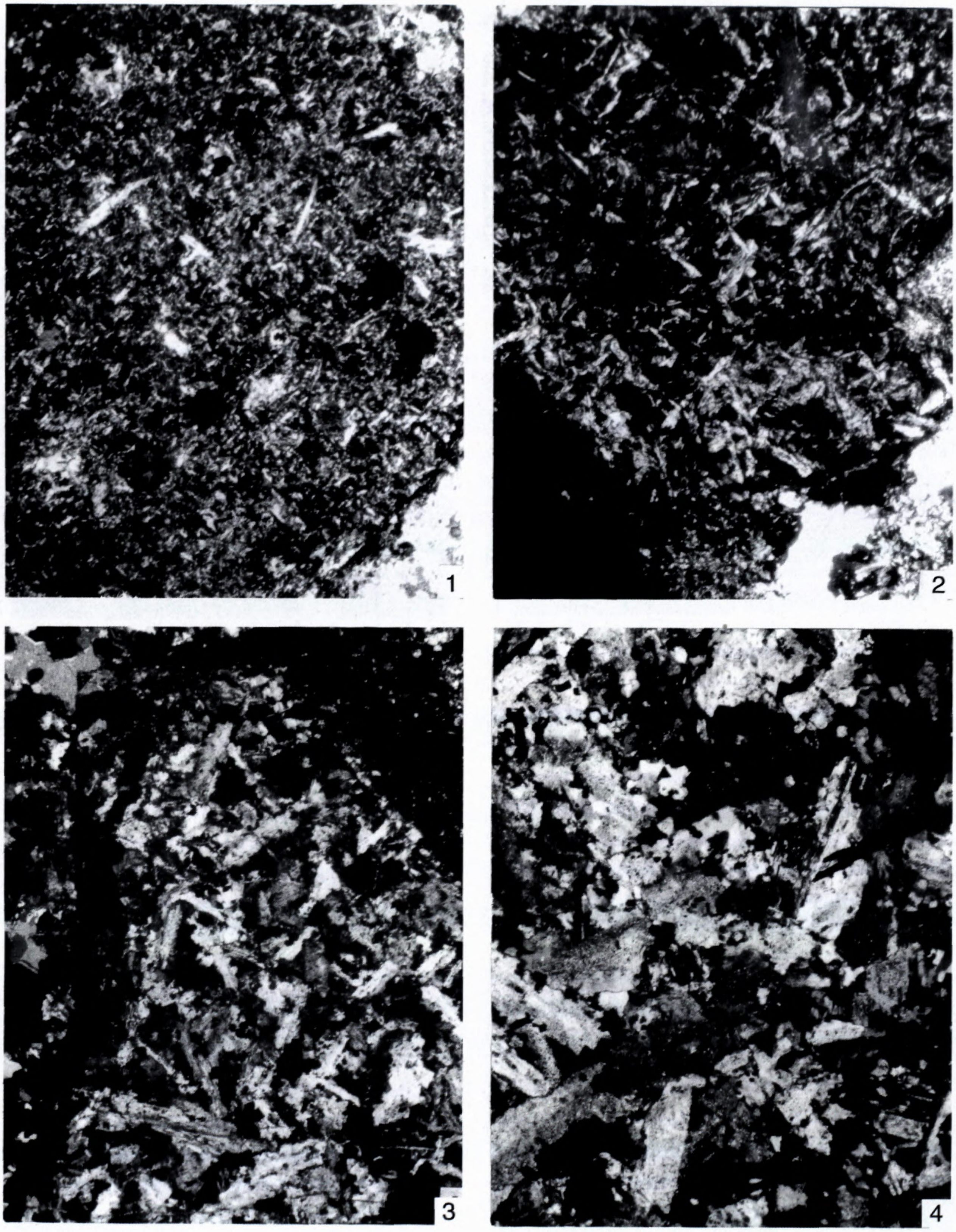
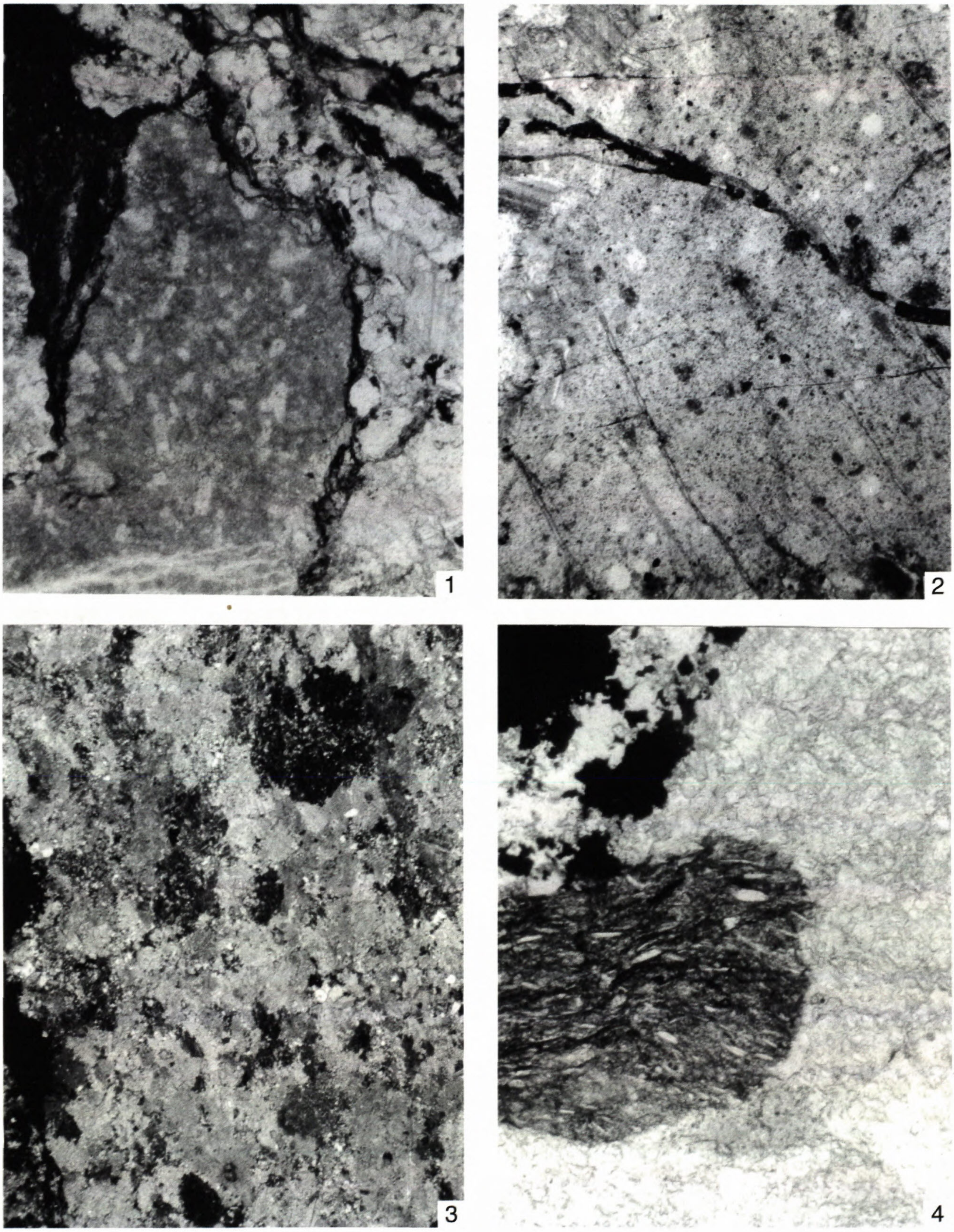


Plate VI



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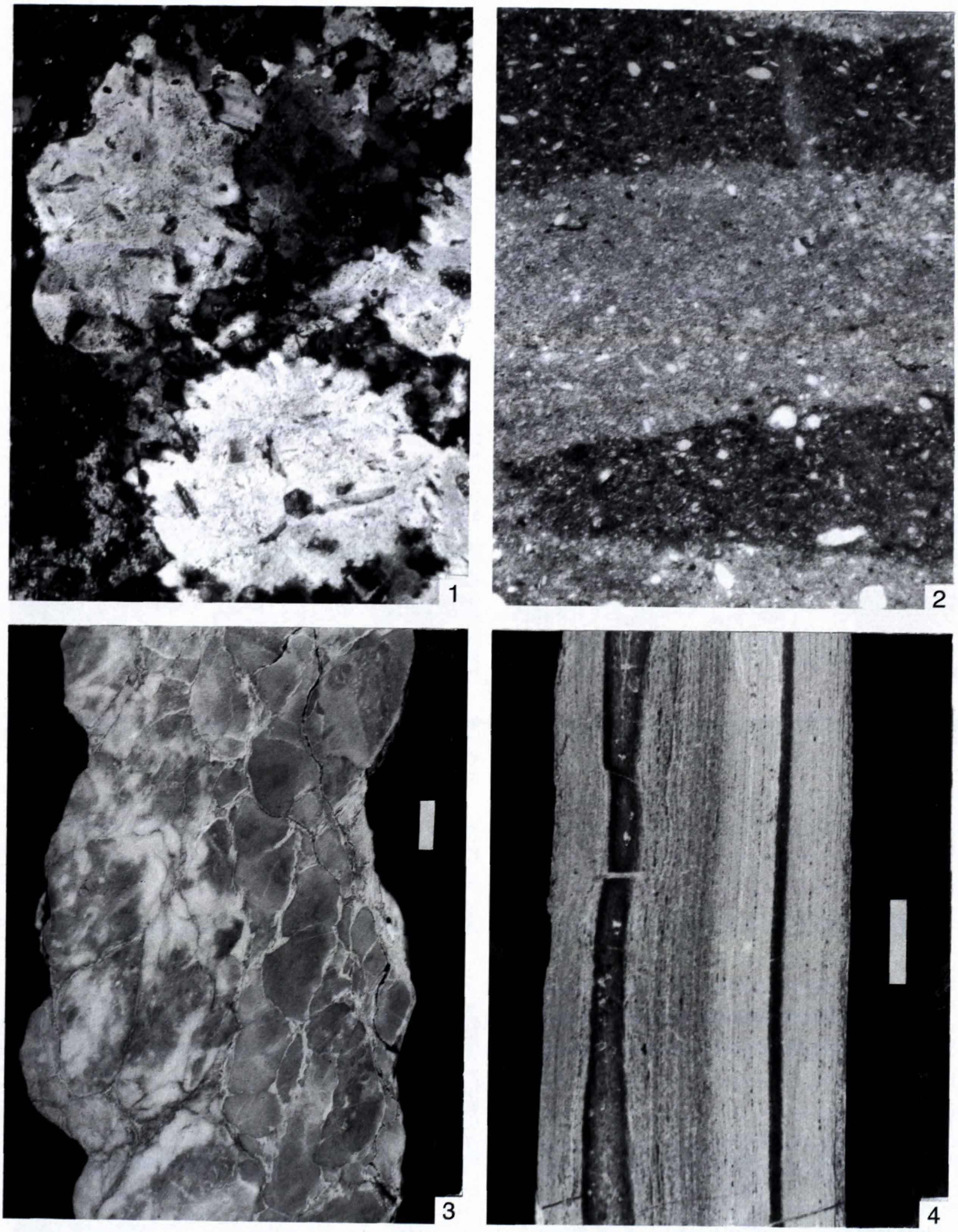

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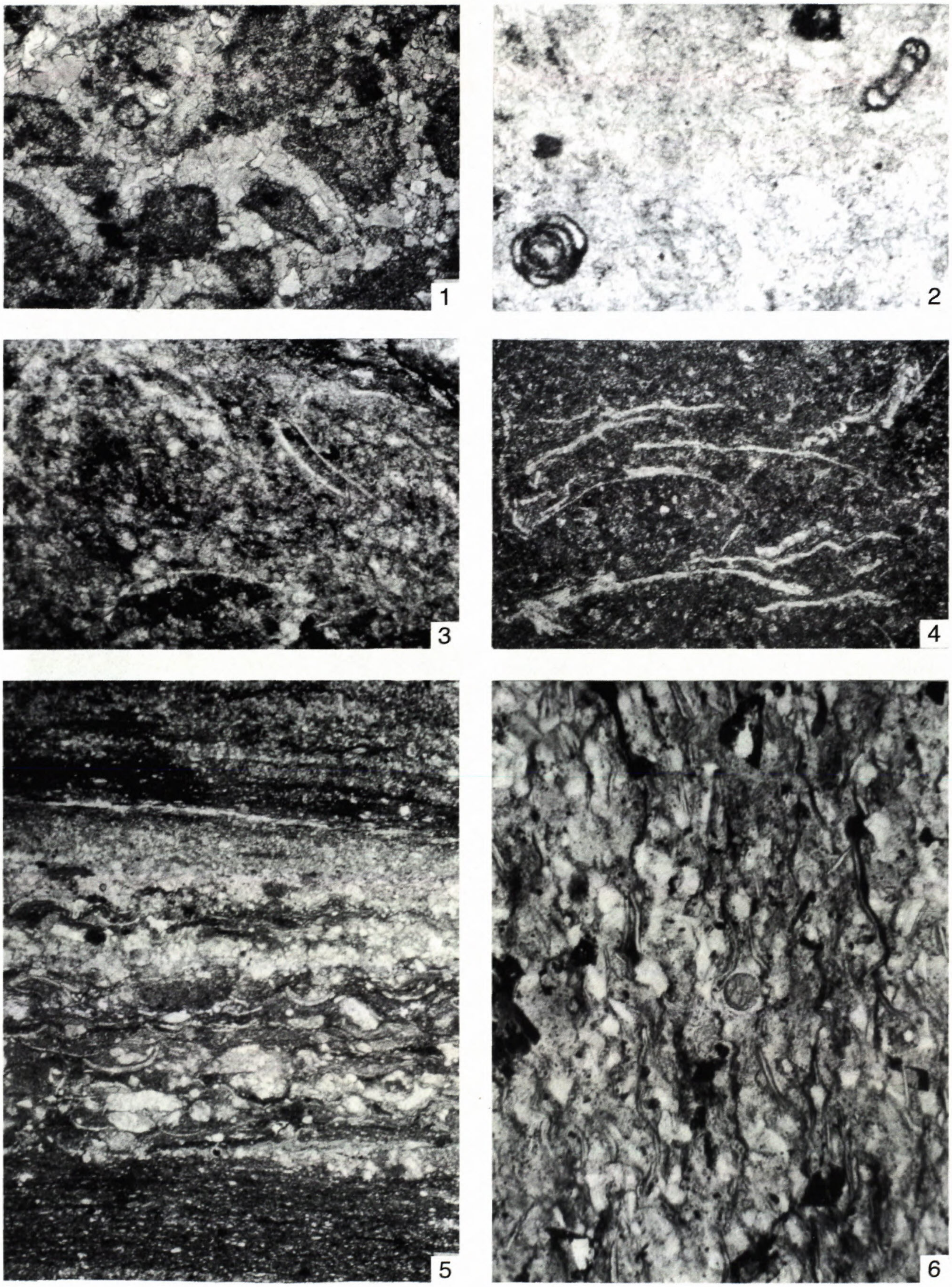


Plate IX

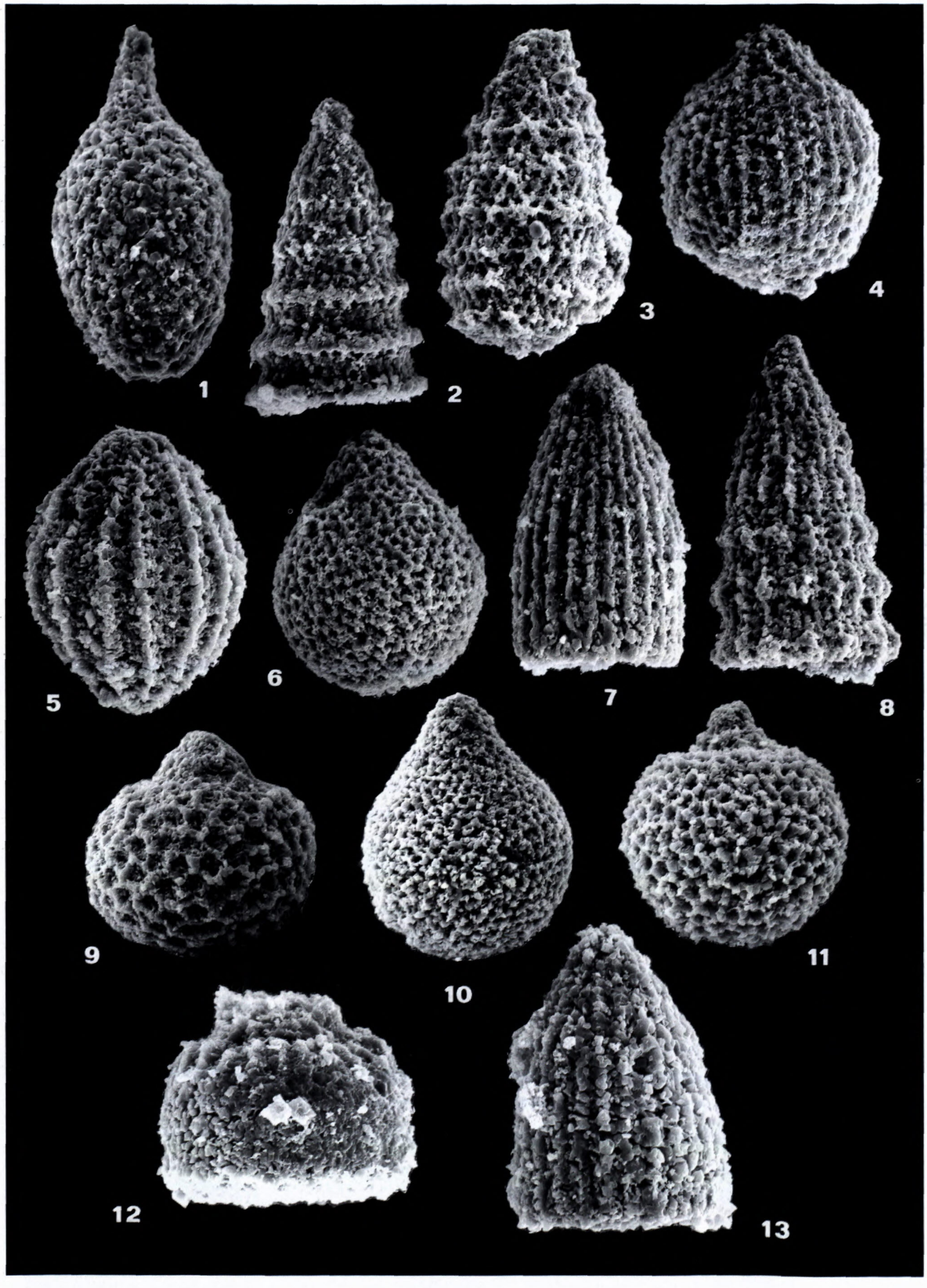


Plate X

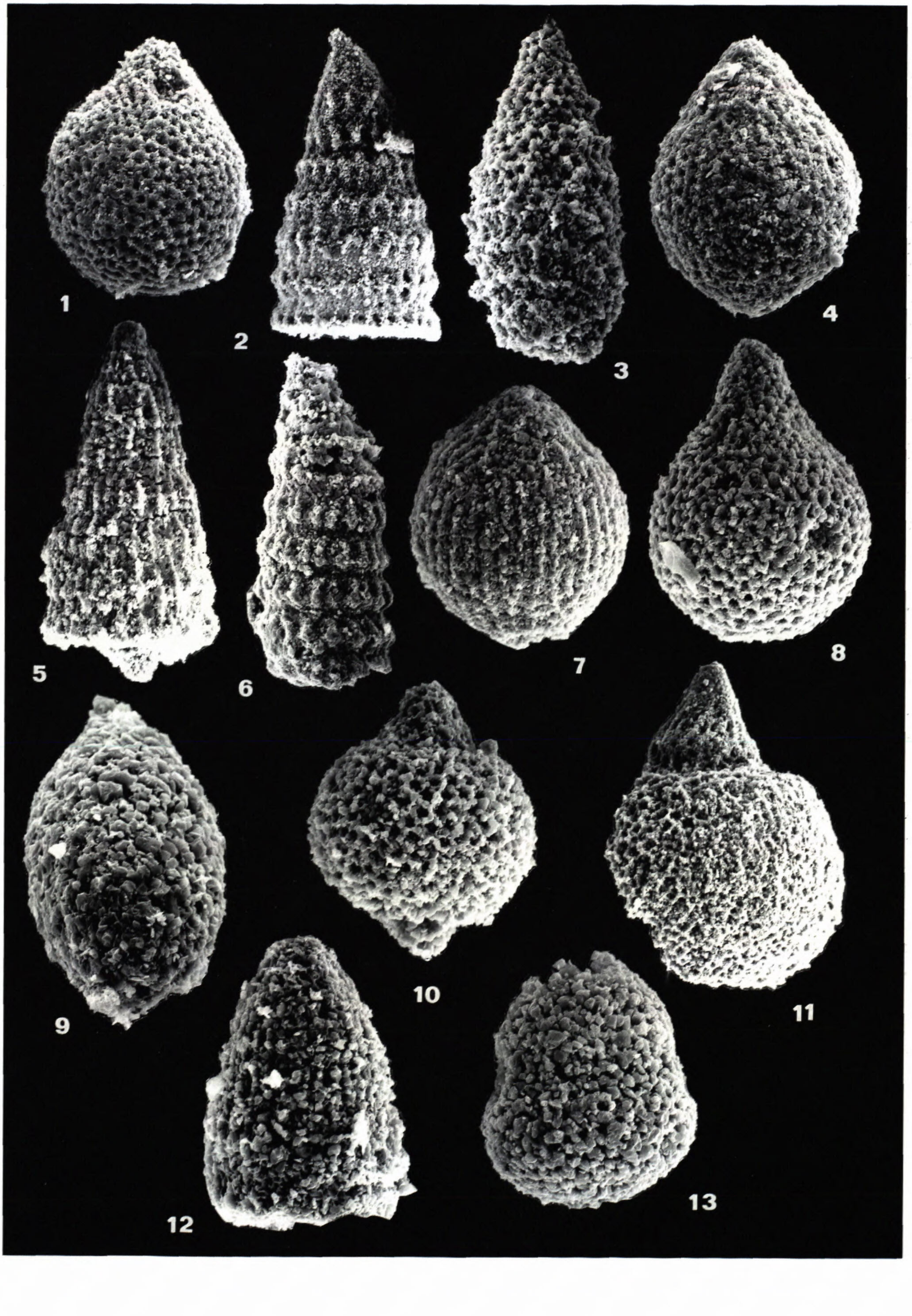


Plate XI

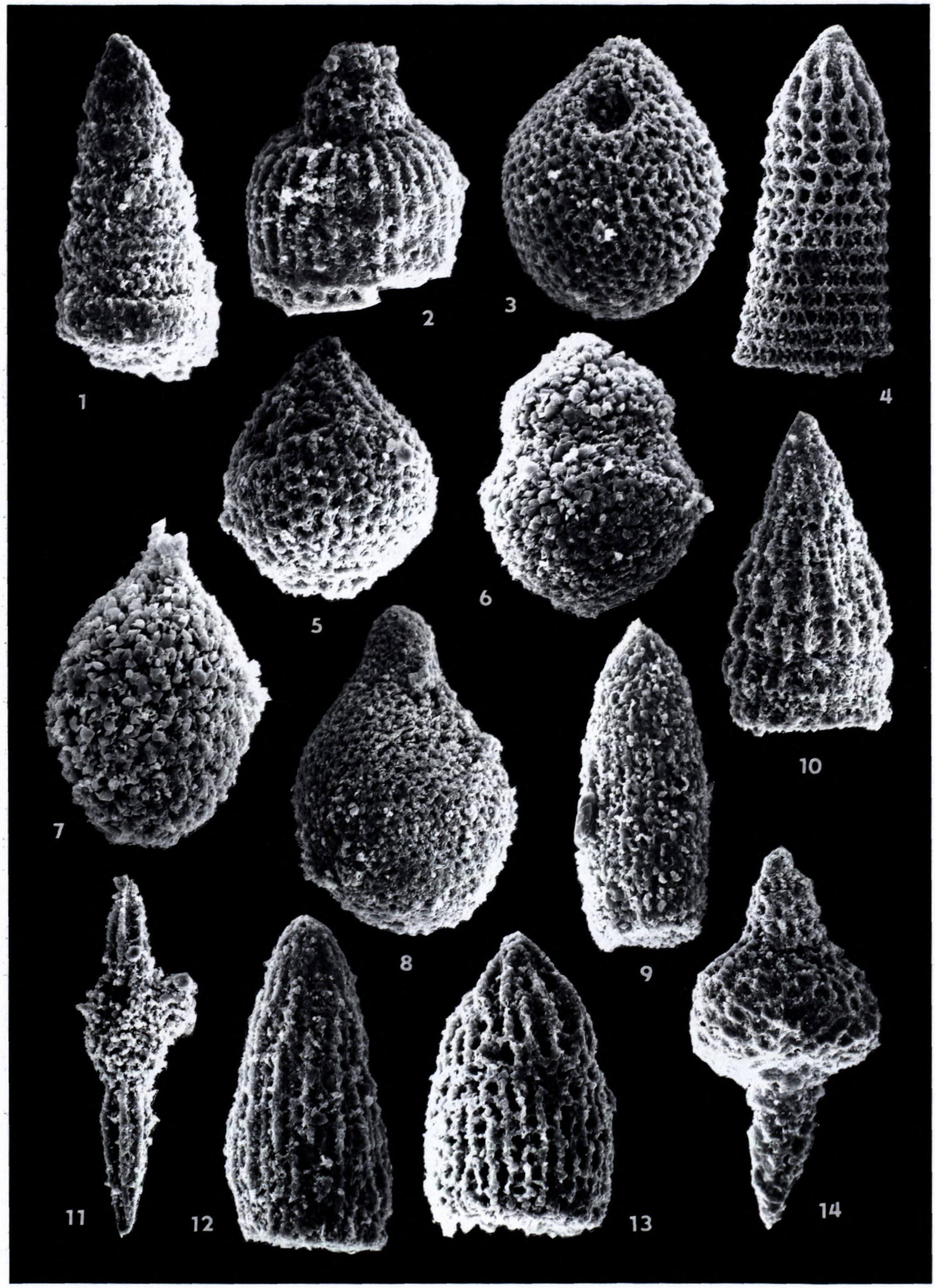


Plate XII

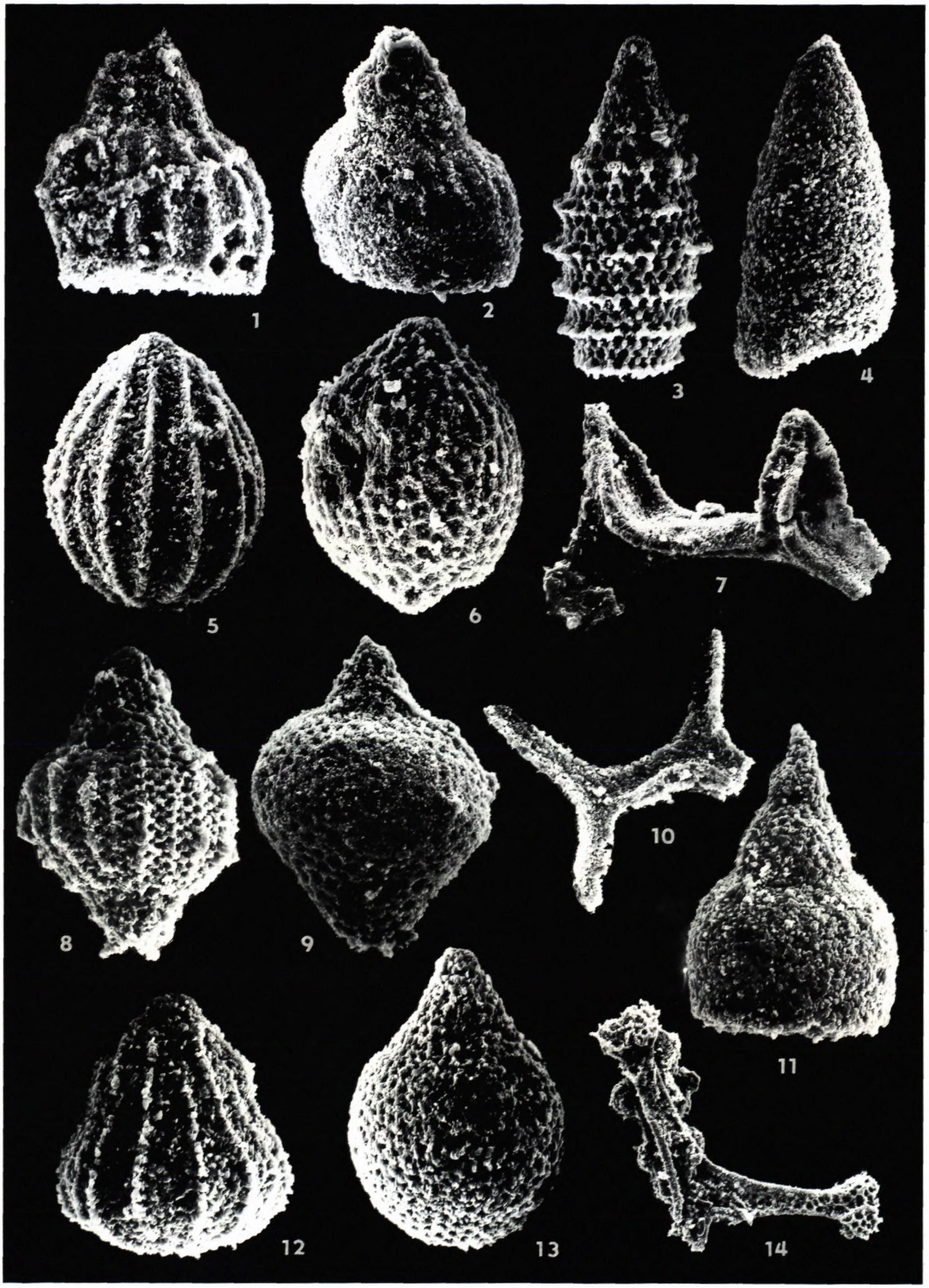


Plate XIII

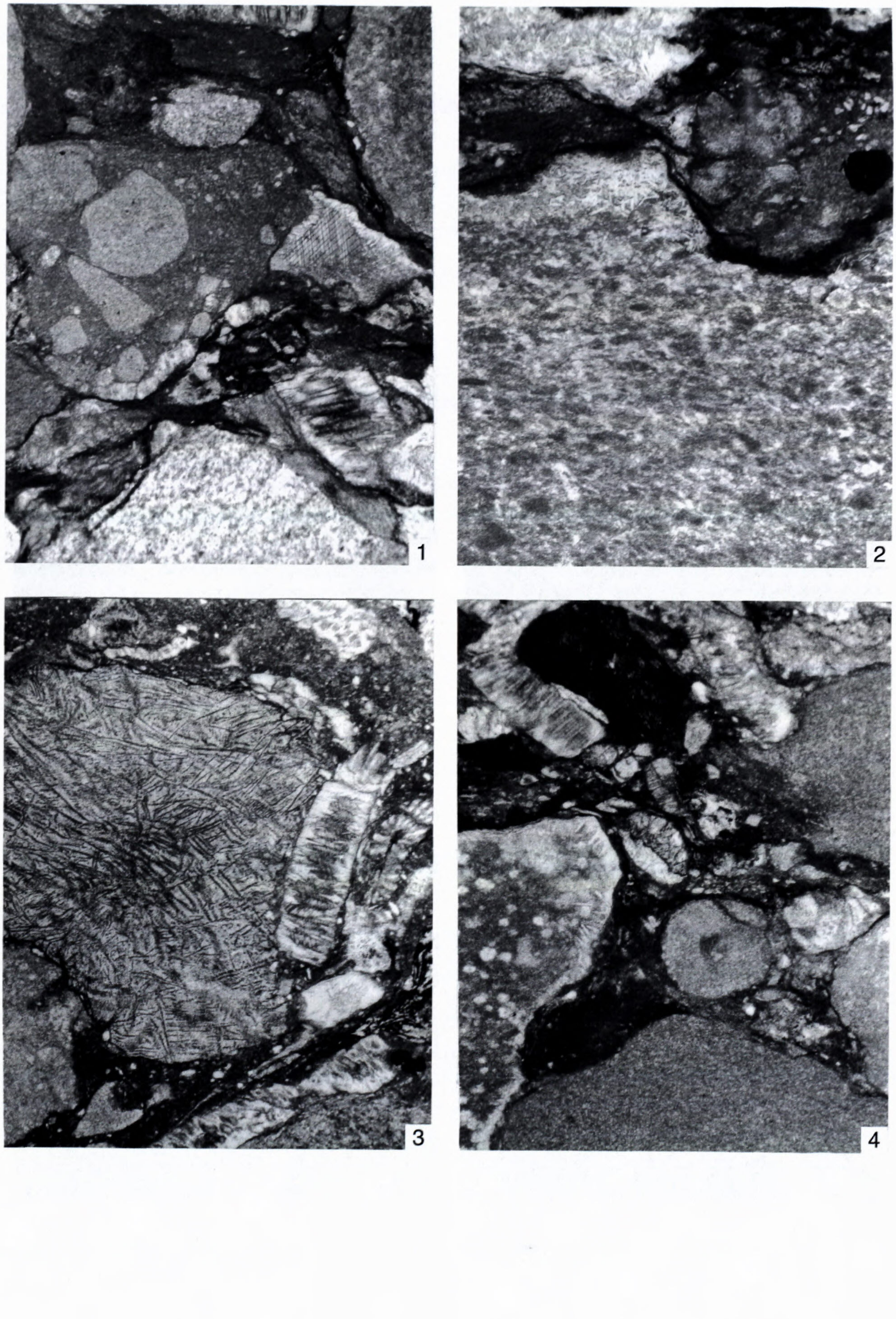


Plate XIV

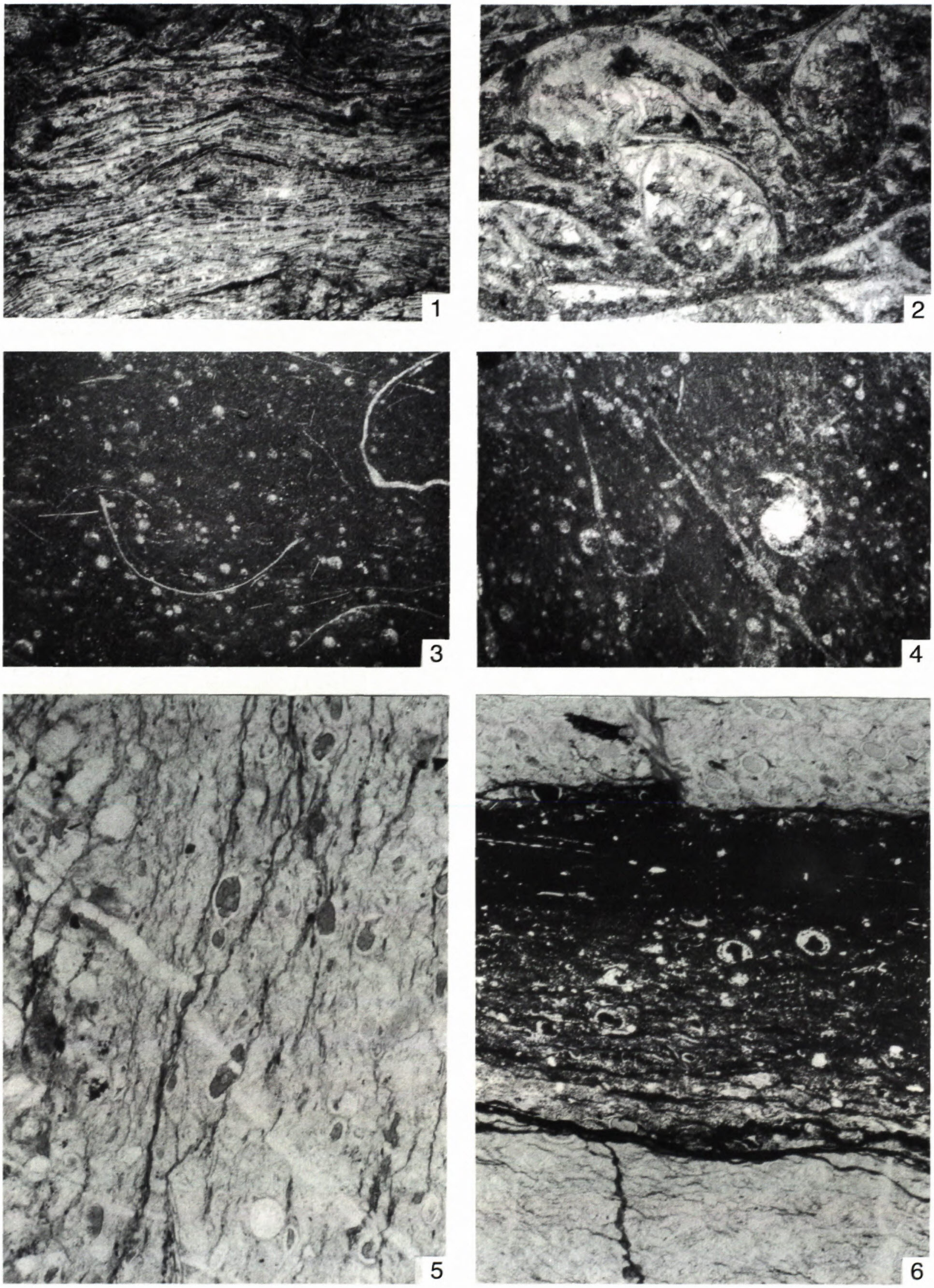


Plate XV

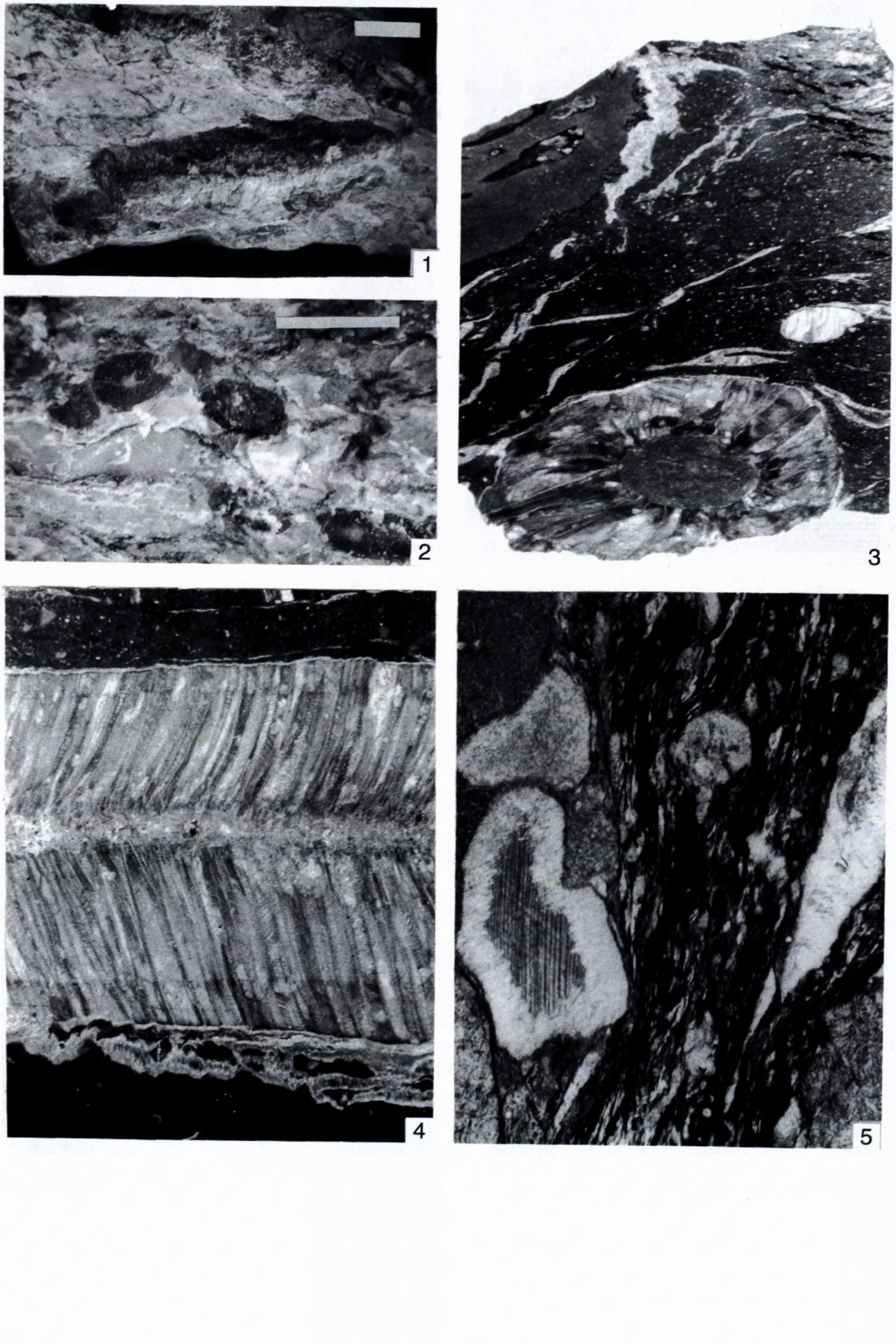
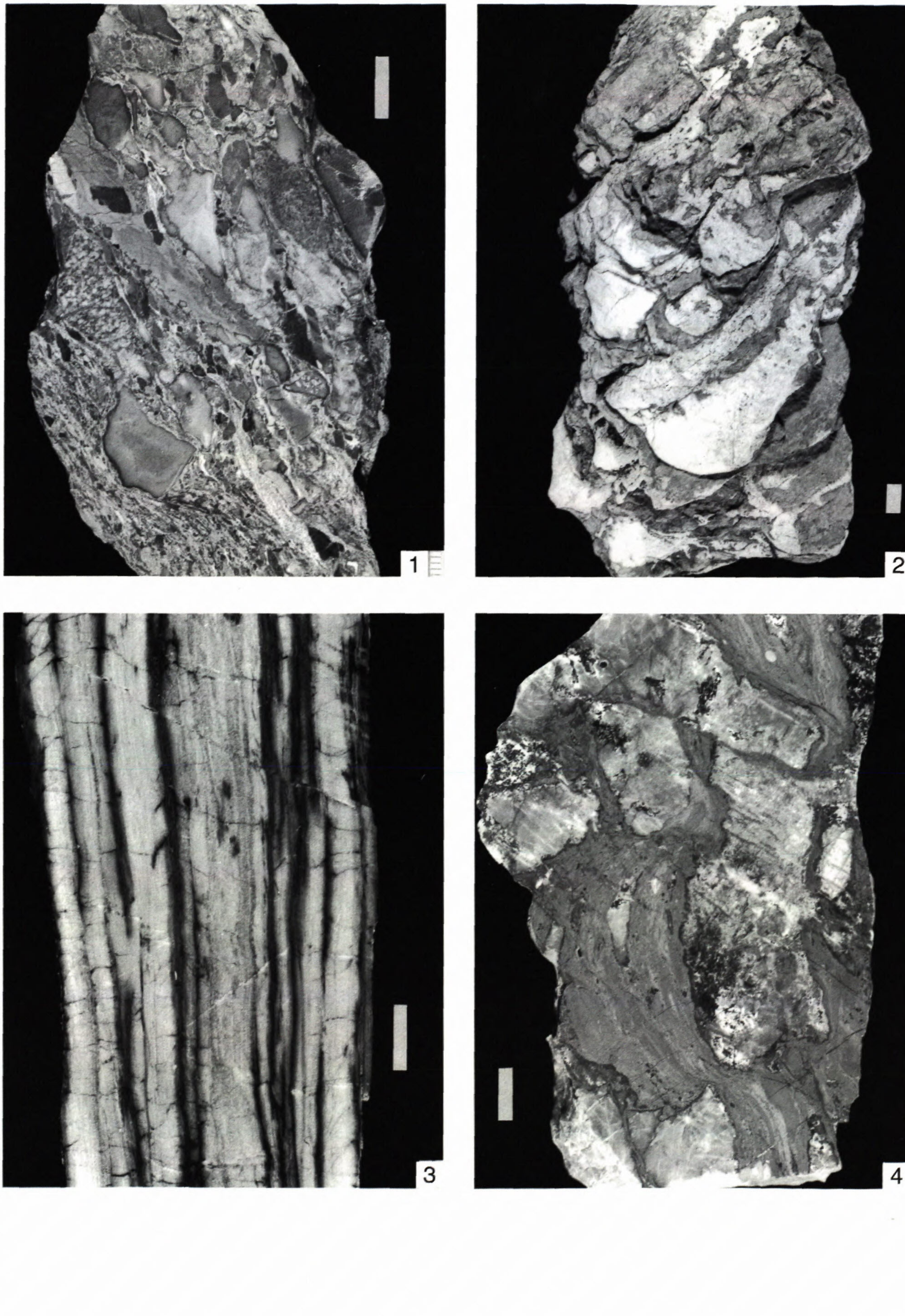


Plate XVI



Slovak Geol. Mag., 4, 4 (1998), 261–273

Bôrka Nappe: high-pressure relic from the subduction-accretion prism of the Meliata ocean (Inner Western Carpathians, Slovakia)

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Abstract: The Bôrka Nappe comprises a variable, discontinuous and tectonically intensively segmented package of the Late Paleozoic and Mesozoic formations which are relatively higher metamorphosed than the surrounding rocks. The common characteristic feature is their alpine metamorphosis in the middle to higher pressure conditions along with the relatively low geotermal gradient reaching 10° C km^{-1}.

In the recent understanding the Bôrka Nappe comprises a rock complex of accretionary prism originated as a result of the Late Triassic – Jurassic subduction of the oceanic bottom and adjacent margins of the Meliata ocean (oceanic and thinned continental crust). The tectonic individualization of the accretionary complex and its transport into the contemporary structural position came even during the younger orogeny stages (in the Early and Middle Cretaceous). In that time the accretionary complex was already modified by high-pressure - low-temperature metamorphism and exhumation and was overthrusted to the contemporary structural position overlying the Gemericum as a complicated nappe structure in ductile-brittle to brittle conditions.

Keywords: Bôrka nappe, Meliaticum, ocean crust subduction, HP/LT metamorphism, subduction-accretionary prism of the Jurassic age, Slovak Karst, Slovenské Rudohorie Mts.,

Introduction

Along the northern margin of the Slovak Karst and in the southeastern part of the Slovenské Rudohorie Mts. between Jasov, Dobšiná and Jelšava numerous isolated or, in places, almost continuous outcrops of the Late Paleozoic and Mesozoic sequences occur, which are relatively higher metamorphosed than the surrounding rocks. They are assigned to the separate tectonic unit termed as Bôrka Nappe. To this nappe HP/LT metamorphic rocks occurring between Jasov, Medzev and Hačava, in the middle part of the Zádiel (Blatná) valley, in the surroundings of Lúčka and Bôrka as well as in the Nižná Slaná Depression, to the west of Štítnik and in the surroundings of Jelšava are assigned (Fig. 1).

The term "Bôrka Nappe" was originally used by Leško and Varga (1980). They divided it as a separate tectonic element in the Western Carpathians and compared it with the southern Penninicum of the Western Alps. They named it after typical development in the Bôrka surroundings (Fig. 2).

The authors assigned to the Bôrka Nappe a complex of dark marly pelites, marls, cherts, basalts, ultrabasic and volcanosedimentary rocks which stratigraphic assignment was not known at that time and which was assumed to represent upper part of the Mesozoic (Jurassic to Early Cretaceous?). According to the recent conception (Mello et al. 1996, 1997) the Bôrka Nappe is lithostratigraphically understood much wider and besides sequences with assumed Triassic – Jurassic age also older rocks, most probably of the Late Paleozoic (Permian) age are assigned to it. The common characteristic feature of all rock sequences is their Alpine metamorphism in the middle to higher pressure conditions along with the relatively low geotermal gradient reaching 10° C km^{-1} (Mazzoli et al. 1992). In order to provide unified terminology of these higher-grade metamorphosed Mesozoic – Late Paleozoic sequences, the term "Bôrka Nappe", already used in the literature, was retained even if the much more typical and complete development of the nappe than in the surroundings of Bôrka is in the area between Jasov and Hačava. In this area it was detailly mapped and described (in that time with different assignment) by Reichwalder (1973) in the past (Fig. 4).

In the recent understanding the Bôrka Nappe comprises a rock complex of accretionary prism originated as a result of the Late Triassic – Jurassic subduction of the oceanic bottom and adjacent margins of the Meliata ocean (oceanic and thinned continental crust). The tectonic individualization of the accretionary complex and its transport into the contemporary structural position came even during the younger orogeny stages (in the Early and Middle Cretaceous). In that time the accretionary complex was already modified by high-pressure - low-temperature metamorphism and exhumation and it was overthrusted to the contemporary structural position

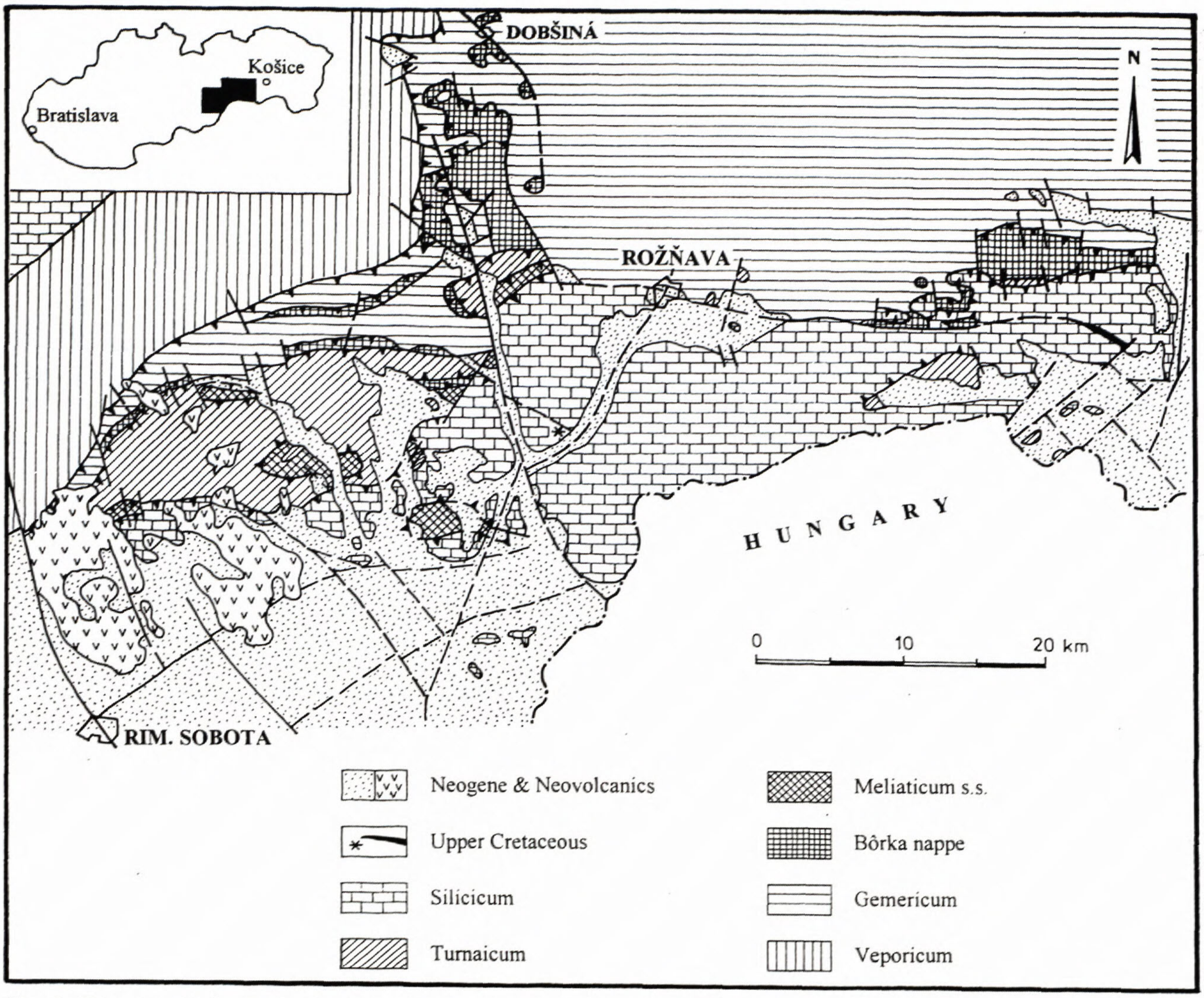


Fig. 1: Extension of the Bôrka Nappe in the northern part of the Slovak Karst and in the southeastern part of the Slovenské Rudohorie Mts.

overlying the Gemericum as a complicated nappe structure in ductile-brittle to brittle conditions.

Lithostratigraphy of the Bôrka nappe

The Bôrka Nappe comprises a variable, discontinuous and tectonically intensively segmented package of the Alpine metamorphosed sedimentary-volcanic rocks of the Late Paleozoic–Mesozoic age (?Permian-?Jurassic). On the basis of the lithology and mutual relationships of the individual lithologic units it is divided into *Jasov Formation, Bučina Formation and Hačava Sequence* with *Dúbrava Formation* in the lower part (Mello et al. 1997, Fig. 3, [Fig. 6 in this article]). Their relationship is tectonic at all sections.

Jasov Formation (?Permian) consists of a complex of metamorphosed, prevailingly clastic deposits usually cropping out as a separate partial structure of the Bôrka Nappe. Although the formation has more lithologic features in common with Rožňava Formation of the Gemeric Gočaltovo Unit, it conspicuosly differs from it by metamorphic and deformational structures suggesting the substantially higher intensity of metamorphic and deformational processes. Based on metamorphic mineral association and $b_{331,\ 060}$ values of K-white micas, the conditions of middle-high pressure regime by the temperature around 470° C during climax of the Alpine metamorphism were proved (Mazzoli et al. 1992).

Lithologically the formation is relatively monotonous. It mostly consists of metapsamites. Conglomerates are restricted to the lower part of the formation but they did not form more conspicuous conglomerate layer. The metapsamites are fining upward and they pass into the sequences with prevailing metasiltstone and metapelite occurrence. The transition between individual types is gradual. The metarhyolites and acid volcanoclastic rocks comprise smaller bodies and lense-like layers mainly in the lower parts of the formation.

Bučina Formation (?Permian) is composed of the variable range of the sedimentary, volcanic and volcanoclastic rocks. Lithologically it resembles the lower parts of the Jasov Formation but the rocks are substantially more siliceous, most probably as a result of silicification

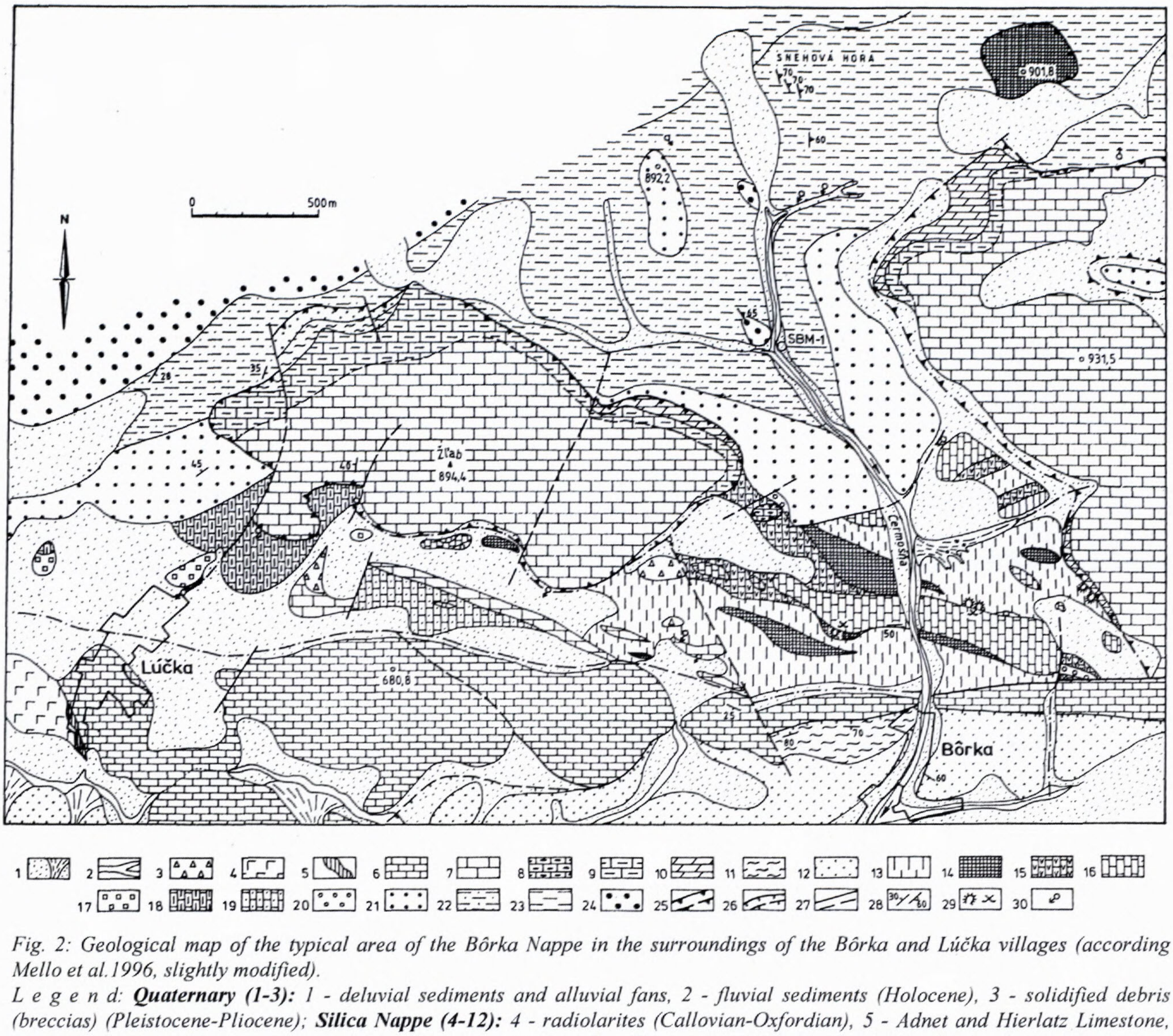


Fig. 2: Geological map of the typical area of the Bôrka Nappe in the surroundings of the Bôrka and Lúčka villages (according Mello et al.1996, slightly modified).

*L e g e n d: **Quaternary (1-3):** 1 - deluvial sediments and alluvial fans, 2 - fluvial sediments (Holocene), 3 - solidified debris (breccias) (Pleistocene-Pliocene); **Silica Nappe (4-12):** 4 - radiolarites (Callovian-Oxfordian), 5 - Adnet and Hierlatz Limestone, varigated breccia (Liassic), 6 - Dachstein limestone (Norian),7 - Wetterstein limestone (Ladinian-Cordevolian), 8 - Reifling limestone (Ladinian), 9 - Steinalm limestone (Anisian), 10 - Gutenstein limestone (Anisian), 11 - Szin Beds (Late Scythian), 12 - Bodvaszilas Beds (Late Scythian), **Bôrka Nappe (13-19):** 13 - metamorphosed dark shales with intercalations of dark sandstones, carbonates and metabasic volcanic rocks (? Triassic-?Jurassic), (14-16): Dúbrava Formation (Middle-Upper Triassic?): 14 - metabasic rocks, often glaucophanites, 15 - metamorphosed light and gray crystalline limestone with admixture of volcanic material, 16 - Honce Limestone: metamorphosed light crystalline limestone, 17 - rauhwackes (approx. boundary between Lower and Middle Triassic, part of them is of tectonic origin), 18 - Jelšava Beds: metamorphosed yellowish-brown limestone with intercalations of metamorphosed shales and marls (Scythian), 19 - "Paklan Beds": metamorphosed yellowish-brown limy sandstone to sandy limestone (Scythian), it can not be excluded that this member belongs to the Turna Nappe, **Gemericum: Gočaltovo Group (Permian) (20-24):** 20 - medium grained oligomict conglomerates, 21 - gray-green bedded and rhytmically laminated quartz sandstone, 22 - gray and green shales and fine grained sandstone, 23 - green and gray shales, 24 - variegated polymict brecciated conglomerates with intercalations of greywackes, sandstones and shales, **Technical explanations (25-30):** 25 - thrust lines, 26 - reverse faults, 27 faults, 28 - strike and dip: of beds; of schistosity, 29 - prospection galleries out of operation, 30 - springs*

connected with the volcanic activity. The most of the rocks posses a conspicuous parallel structure. The clasts in the metaconglomerates are markedly compressed, often with the expressive linear stretching. Similar stretching as a result of intensive shear deformation also show some porphyroclasts and porphyric phenocrysts in rhyolites and rhyolitic volcanoclastics (Plate I, fig. 3-4). The inventory of the deformation structure is typical for the shear zones in the brittle-ductile and ductile conditions.

Hačava Sequence (?Triassic - ?Jurassic) has a complicated, imbricated internal structure. The frequent tectonic contact of the different lithologic members, shortage of the biostratigraphic data and intensive metamorphism connected with the development of metamorphic schistosity does not provide reliable data for reconstruction of its stratigraphic succession. In spite of this, a probable lithostratigraphic succession is possible to reconstruct using consistent metasedimentary and metavolcanic rock associations at the majority of the occurrences which are assigned to the Bôrka Nappe, reconstruction of local bed successions and observations of relatively frequent mutual transitions among some lithologic members. The succession is to a great extent correlable with palaeofacial change trends in the adjacent tectonic units (Turnaicum, Meliaticum) reflecting palaeotectonic evolution of the wider sedimentary environment including opening and closure of the "Meliata" ocean and the evolution of the adjacent slope areas.

Fig 3: Area of the type locality of the Bôrka nappe norh of the Bôrka village at the norhern margin of the Slovak Karst - 1. Silica Nappe, 2. Bôrka nappe, 3. Gemericum: Gočaltovo Group (Permian), Photo by P. Reichwalder

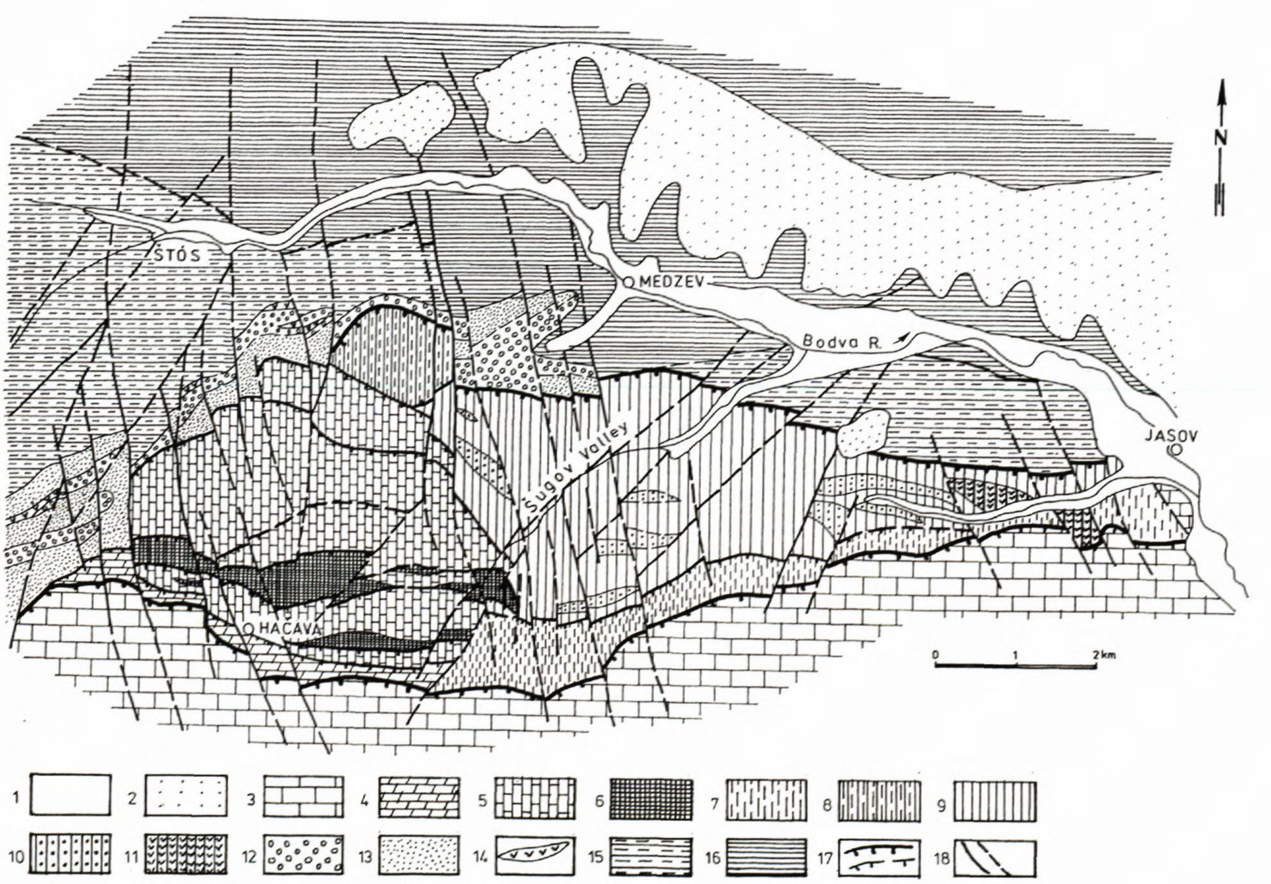


Fig. 4: Simplified geological map of the Bôrka Nappe between Hačava and Jasov (after Reichwalder in Mello et al. 1996). 1. Quaternary deposits undivided, 2. Neogene deposits undivided; ***3. Silica Nappe*** *(Triassic - Jurassic);* ***4. Turňa Nappe*** *(Triassic);* ***Bôrka Nappe (5-11):*** *5. dolomites, crystalline limestones, locally with volcanic material, 6. glaucophanites (5 and 6 - Dúbrava Formation), 7 dark grey and green metapelites (5 - 7 Hačava Sequence; ?Triassic - ?Jurassic), 8. Bučina Formation (?Permian), 9. metapsamites, metapelites, 10. metaconglomerates, 11. metarhyolits (9 - 11 Jasov Formation - ?Permian);* ***Gemericum (12-16):*** *Gočaltovo Group (12-14)**:** 12. conglomerates, 13. sandstones and shales, 14. rhyolites and dacites, 15. Štós Formation, 16. Gelnica Group**,** 17. nappe overthrusts and reverse faults, 18. faults (normal and strike - slip).*

Fig. 5. View of area of tectonic contacts of the Silica Nappe (far right), the Turna Nappe (above the church and at fields in the foreground) and the Bôrka Nappe (mostly marbles and blueschists of the Dúbrava Formation in the central and left part of the ridge) along the northern margin of the Slovak Karst near the Hačava village. Photo by P. Reichwalder.

The rock record in its lower part (*Dúbrava Formation*) even if it is to a great extent fragmentary, suggests a gradual evolution from the pre-rift stadium characterized by terrigenous and probably also terrigenous-evaporitic facies in the lower part, through a probably shorter stadium of a carbonate platform to the stadium of an intensive rifting already at the beginning of the Middle Triassic (Middle Anisian). This stadium was accompanied by collapse of carbonate platform and locally by intensive manifestation of basic volcanism. Frequently observed synchronous products of basic volcanism and carbonate deposition (Fig. 9) point to time relation of volcanism with the initial phase of rifting in the continental crust condition preceding the formation of oceanic depositional environment of the Meliaticum (Meliata ocean). The uppermost parts of the reconstructed succession of the Hačava Sequence consists of non-calcareous green, gray and black metaclaystones containing thinner interlayers of metasiltstones and metapsamites and of minor rock bodies (probable of olistolith characters) occurring in the underlying rocks. They represent pelagic and turbiditic deposits of post-rift (oceanic) stadium. Rarely dm layers of redeposited acid volcaniclastic material (Nižná Slaná Depression SW of Markuška) occur. Stratigraphicaly they probably reach up to Early-Middle Jurassic.

The lowermost part of the carbonate complex consists of yellow and gray granulous, partly cellular dolomites. They are in the lowermost part of the pale crystalline limestone complex as thin (max. 10 –15 cm), continual and lense-like pinching out layers. From the lithofacial point of view they represent the commencement of the carbonate deposition. They represent a characteristic marker horizon correlable with Gutenstein Dolomites of the adjacent tectonic units (particularly with the Turnaicum Nappe). They often posses cellular structure (rauwacks) and their origin may be tectonic in many cases. The contact of the dolomites with underlying rocks is almost exclusively tectonic. They most often crop out along thrust and overfault planes restricting partial nappes and nappe slices (duplexes) commonly occurring at the base of carbonate rock sequences. This is possible to observe in the surroundings of Hačava and Šugov valley as well as in Nižná Slaná Depression (Fig. 8).

The light gray and white crystalline limestones (marbles) represent a characteristic and most widespread lithotyp of Dúbrava Formation. They are light gray and white, massive, unbedded, on the surface often faintly karstified and mostly intensively split. They form morphologically conspicuous hills (e.g. hills Jelení vrch, Zakúrený vrch, Špičák, Javorina and others in the area between Medzev and Hačava). In the area of the Nižná Slaná Depression these hills are mainly represented by elevation points of the Dúbrava hill north of Ochtina village, Ždiar and Starý háj hills east and northeast of Slavoška village and also by some hills in the area south of Chyžné village and north of Jelšava town. These limestones also comprises striking klippen belts in the surroundings of Jelšava). They usually reach thickness of tens to hundreds of metres. Common metamorphic foliation also suggests a possibility of secondary (tectonic) increase of their thickness. They are prevailingly of monomineral composition. They consist of medium- to coarse-grained calcite, locally with indication of preferred shape orientation. The marmors are mainly in the lower

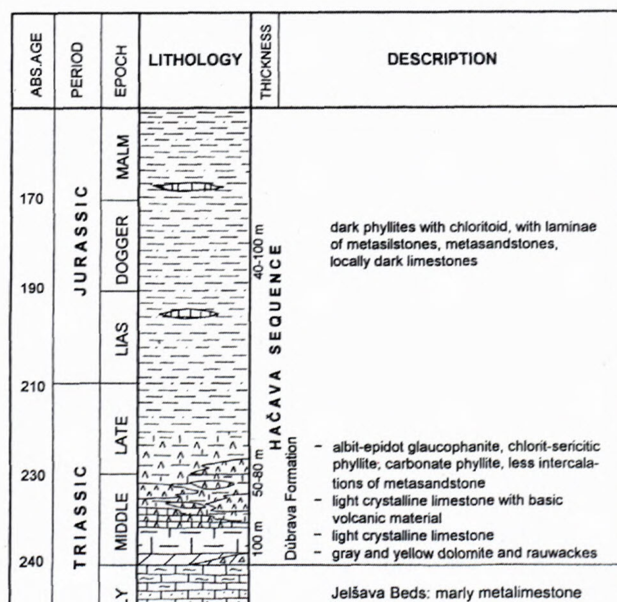


Fig. 6: Lithostratigraphy of the Bôrka Nappe (Reichwalder - Vozárová - Mello, 1997).

Fig. 7: Outlier of the Silica Nappe tectonically overlying rock sequence of the Bôrka Nappe on the Radzim Hill, 5 km SW of the Dobšiná town in the area of Nižná Slaná Depression (see geological map, fig. 8). Photo by P. Reichwalder.

part very pure and they contain only scarcely higher admixture of other minerals (quartz, limonitised Fe-carbonates). As to their appearance, composition and structural position in the bed sequence they are analogous to the similar crystalline limestones occurring in the adjacent tectonic units (Turnaicum, Meliaticum). The upper stratigraphic range of these units is restricted by the Pelsonian age of the red pelagic limestones filling neptunic dykes in these limestones. Originally, they probably represented shallow-water reef and lagoonal (Steinalm) limestones of carbonate flats. Their pale to white colour does not have to be original, it may be a result of higher degree of metamorphic processes. Therefore it is not possible to exclude a possibility that a part of the carbonate sequence, especially in its upper part, could be composed of pelagic, more deep-water types of limestones which originally were more variegated.

The crystalline carbonates of the *Dúbrava Formation* generally have low values of Sr/Ca ratio as well as contents of Al_2O_3, Mn, K, U, Th and rare earth. The mean value of REE from 4 samples of crystalline limestones is 4,75 ppm. In the underlying crystalline dolomites the content of Na, Mn, U, Th and also of REE (the mean from 3 samples = 8.66 ppm) is relatively lower. However, the crystalline carbonates of Dúbrava Formation are generally strongly depleted of REE with a lower degree of fractionation LREE vs. HREE in distribution curves. It prefers their deep-water origin or a basin located in a considerable distance from a terrestric source. The isotopic content of O and C is influenced by a high degree of metamorphism (Vozárová et al. 1995).

The *slaty crystalline limestones* are common lithologic type, particularly in the northern part of Hačava surroundings.

The boundary with the light crystalline limestones is gradual, especially if their contact is not tectonized. The gradual transition is connected with increase of clastic, mainly volcanic material. The proportion and form of occurrence of this clastic material in the carbonate matrix is considerably changeable varying from regularly disseminated fine-grained tuff material through its concentration in more continuous layers up to occurrence of basalt fragments or more continuous layers of basaltic lavas. The characteristics of the basic volcanic material occurrence in the carbonate deposits points to partly contemporaneous carbonate deposition and basic volcanism (Reichwalder 1971, 1973) at least during the initial stages of the volcanic activity. A variety of rocks differing by mineral composition as well as textural and structural characteristics exists as a result of the original composition and subsequent metamorphic and depositional processes. Non-carbonate minerals are composed of chlorite, fengite, paragonite, albite, epidote, actinolite and locally also by glaucophane. The occurrence of quartz and some accessory and secondary minerals is also relatively abundant. The schistosity is of metamorphic origin and it is emphasized by a preferred orientation of phylosilicate minerals. Less frequent are crystalline limestones with preserved more continuous layers of volcanoclastic material which is locally emphasized by a selective weathering. These layers often show very intensive folding (Plate II, Fig. 1) while at least two time and kinematic different types of fold deformation can be observed.

The most characteristic lithologic types of *Dúbrava Formation* are metabasic rocks. They occur almost at all outcrops of the Bôrka Nappe. The metabasic rocks are very often changed in the HP/LT conditions. They are represented by a wide range of metamorphosed basic volcanic, volcanoclastic and maybe also deeper igneous rocks. They show high variability of petrologic types from metabasalts through green schists to glaucophanites. This variability reflects not only substantial diversity in the original composition of source rocks but mainly varied metamorphic conditions from the green schists facies up to facies of blue (glaucophanite) schists during both progradational and retrogradational stage (Mazzoli et al. 1992, Vozárová 1993), Ivan 7Kronome, 1996, Faryad 1995, Janák in Reichwalder et al. 1995).

HP/LT metamorphism of these and other rocks of the Bôrka Nappe is related to the subduction-accretionary process in the stage of the closure of Meliata ocean during the Jurassic and to the fast exhumation of the accre-

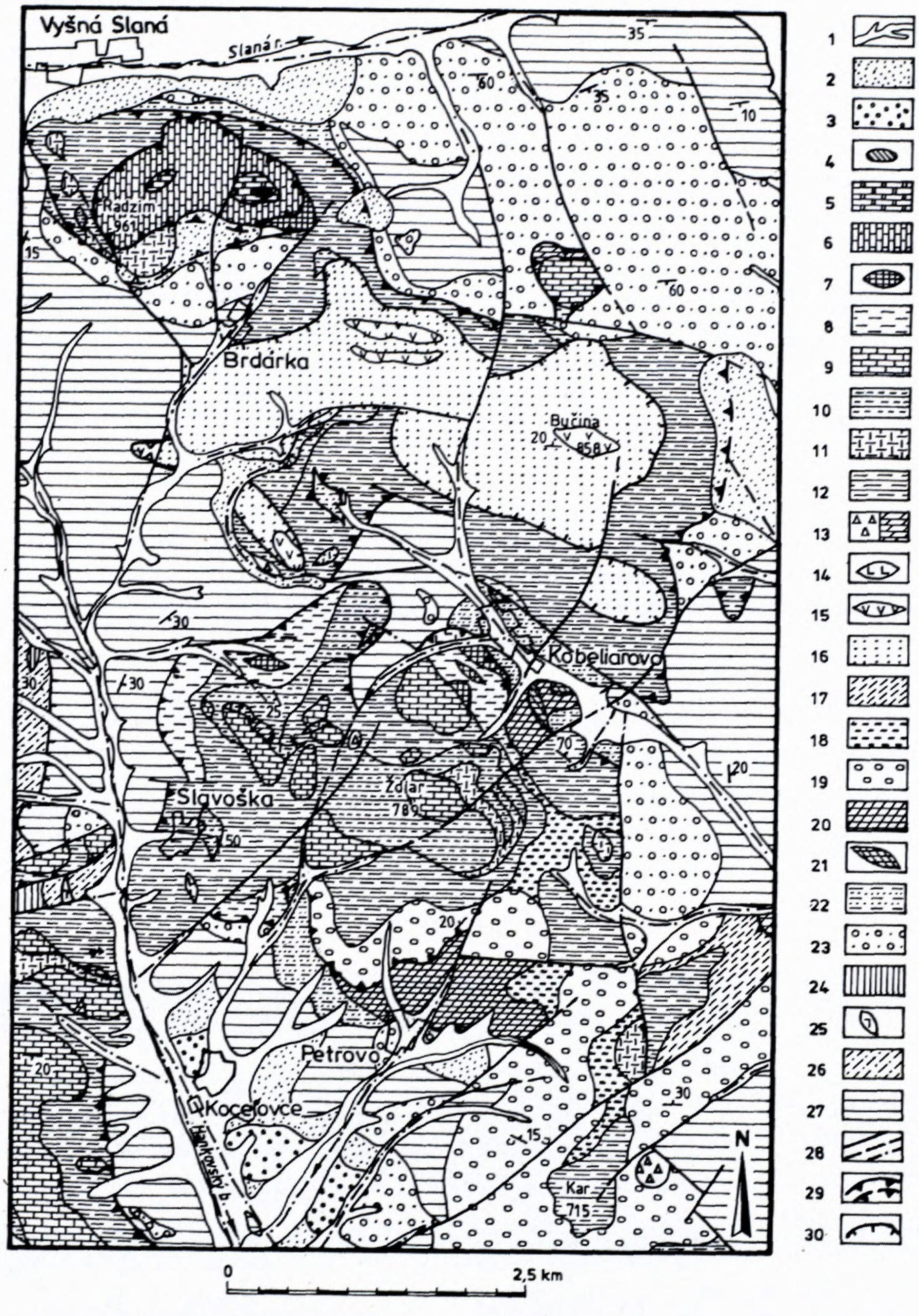


Fig. 8: Geological map of the Bôrka Nappe in the Nižná Slaná Depression (after Mello and Vozár [Paleozoic formations] in Madarás et al.,1995).

Quaternary (1-2): *1 - fluvial and proluvial sediments: sandy and loamy gravels, loams and clays, 2 - deluvial sediments: loamy-stony, loamy-sandy and loamy sediments;* ***Tertiary (3):*** *3 - gravels (Pliocene);* ***Silicicum: Silica Nappe (4-6):*** *4 - Nadaska limestone (Illyrian-Fassanian), 5 - Steinalm limestone (Pelsonian-Illyrian), 6 - Gutenstein limestone (Anisian);* ***Bôrka nappe (7-19): Partial nappe of Ždiar, Hačava sequence and Dúbrava Formation (7-14):*** *7 -dark shaly crystalline limestone, 8 - dark and gray shales, dark phyllites, metasandstones, locally with interlayers of dark limestones, 9 - light crystalline limestone, 10 - light, yellow-brown to brown bedded crystalline limestone with admixture of volcanic material, 11 - metabasalts and their tuffs, glaucophanites, 12 - gray and green sericitic - chloritic phyllites, often with predominance of metabaslt tuffs and tuffites, 13 - rauhwackes and dolomites, 14 - serpentinites;* ***Partial nappe (slice) of Bučina, Bučina Formation (Permian) (15-16):*** *15 - metavolcanics - rhyolites, 16 - metamorphosed acid vulcanoclastics, sandstones, shales;* ***Partial nappe (slice) of Filipka, Filipka Formation (Permian) (17-19):*** *17 - sericitic, sericitic - chloritic and chloritoid phyllites, 18 - metasandstones, 19 - metamorphosed oligomict conglomerates;* ***Gemericum (20-27); Kobeliarovo Group (Triassic) (20-22):*** *20 - light crystalline limestone (Anisian-Ladinian), 21 - gray dolomite (Anisian), 22 -violet and green sandstones and shales (Scythian);* ***Gočaltovo Group, Rožňava Formation (Permian) (23):*** *23 -sericitic, sericitic - chloritic phyllites, metarhyolites and metadacites, their tuffs and tuffites, oligomict conglomerates, unstratified sandstones;* ***Ochtiná Group (Early Carboniferous) (24-26):*** *24 - phyllites, metasandstones, 25 - dark limestones, 26 - metabasalts and their tuffs;* ***Gelnica Group (Late Cambrian - Devonian) (27):*** *27 - Gelnica Group alltogether (phyllites, metasandstones, porphyroids, lydites, etc.);* ***Technical explanations (28-30):*** *28 - faults, 29 - overthrusts, 30 - slices.*

tionary prism. Macroscopically, these rocks are bluegray, bluegreen up to graygreen (usually as a function of occurrence and quantity of glaucophane), fine- to medium-grained, massive, but also with conspicuous foliation and lineation as a result of preferred orientation of glaucophane and other minerals (fengite, chlorite, aktinolite), respectivelly. Mineralogically they mainly consists of glaucophane (crossit), albite, epidote, chlorite, fengite, paragonite, garnet, titanite (leukoxen), magnetite, hematite, quartz (Kamenický 1957, Reichwalder 1970, 1973, Howie & Walsh 1982, Reichwalder et al. 1995, Faryad 1995). Relic primary magmatic structures are occasionally preserved, especially in more massive rock types (Ivan & Kronome, 1996). Locally relics of pillow-lava structure are preserved, even if they are never very conspicuous. The glaucophanite bodies in the surroundings of Hačava are most extensive in the West Carpathians. The greatest of them is 3 km long and its maximum thickness more than 100 m. Its composition is relatively heterogenous and its boundary in relation to the adjacent rocks mainly sharp (tectonic).

Regarding mineralogic composition of the metabasalts, associations of Gln + Chl + Ep + Ab + Ttn ± Phn and Na – Px + Gln + Chl + Ep + Ttn ± Phn indicate metamorphism in the blue schist facies conditions (Faryad, 1995, Faryad, Henjes-Kunst, 1997). This main metamorphic event was replaced by a stadium of isothermal decompression accompanied by mineral association of Act + Chl + Ep + Ab (Mazzoli & Vozárová 1998).

In spite of alkali and light elements mobility during metamorphism, geochemistry of metabasalts suggests OFB or BABB geotectonic environment. The most of normalized REE distribution curves show enrichment in LREE, relatively high La/Sm ratio and depletion in Lu, indicating a striking E-MORB afinity. Minor part of samples shows N-MORB afinity (Ivan & Kronome 1996, Mazzoli & Vozárová 1998).

Locally layers of conspicuously sliced rocks of phyllite character, having green, grayish green up to darkgray colour, occur in the upper parts of the metabasics complex. They probably are rocks having tuff characteristics and locally abundant carbonate matrix.

The metapelites comprise the uppermost part of the Hačava sequence. They are dark gray to black, but also green, often laminated and spotty, non-calcareous metapelites and metasiltstones. They mostly consist of quartz and sericite (fengite, paragonite). The chloritoid occurrence, usually in the form of slat porphyroblasts and aggregates of sheaf shape. A high content of graphitic pigment resulting in dark rock coloration is also typical. The blocks consisting of more rock types known from the Bôrka Nappe, which occur in these metapelites, suggests their interpretation as olistoliths. Based on the occurrence of thinner metasiltstones layers and fine-grained metapsamites in the non-calcareous metapelites it is possible to relate this formation to the distal turbidite facies. Scarcely they contain dm layers of graded redeposited acid volcanoclastics. The rocks are characterized by a striking

Fig. 9: Outcrop of the metabasalt (glaucophanite) fragments in the marble matrix of the Dúbrava Formation of the Bôrka Nappe in the Šugov Valley, 3 km SSW of the Medzev town. Photo by P. Reichwalder.

development of the crenulation cleavage and their frequent spotteness is caused by shearing and pulling away of the original laminae.

The following associations of metamorphous minerals were described in the metasediments: Ms + Pg + Ab; Cld + Chl + Ms + Pg; Cld + Ep + ± Gln; Grt + Gln + Ms (±Pg) ± Bt; Chl + Grt + Ms ± Bt. The common accessory components are quartz, graphite and lower amounts of rutile and titanite. Such a variability of metamorphic mineral occurrences corresponds to the variability of the protolite composition. Turbidite deposits were typical by alternation of Al rich layers with layers having high Fe/Mg ratio and admixture of volcanoclastic material (mostly basic, rarely also acid).

Two degrees of metamorphism were also distinguished in metapellites. The older phase is represented by association Cld (I.) +Chl + Ab + Phn ± Pg and Gln + Grt + Ab + Phn ± Pg. It represents HP/LT phase already documented by $b_{331,060}$ values of K – white mica (Árkai & Kovács 1986; Mazzoli et al. 1992). The younger, low-pressure phase is characteristic by glaucophane destabilization and its substitution by Chl + Qtz ± Ab. The mineral associations Grt + Chl + Ms + Bt + Ab and Cld (II.) + Chl + Ms + Ab also corresponds to this stage (Mazzoli & Vozárová 1998).

Considering the latest interpretations of Meliaticum (s.s.) as a Jurassic olistostrome complex (olistostrome melange) in which other rocks only represent olistoliths in the Jurassic turbidites, a question appears if it is not analogue in the case of Hačava Sequence of the Bôrka Nappe. Even if we can not unambiguously exclude this idea and to the certain extent it is suggested by the described formation, the more probable is that in the case of the Bôrka Nappe it is subduction-accretionary complex. The extensive bodies of crystalline limestones and glaucophanites represent tectonically divided duplexes and tectonic slices. Even if they were exhumed to nearsurface conditions, they have been stripped out, except small exceptions, by erosion only during the collision stage. At that time they were incorporated (obducted) into essentially different metamorphic environment. It is manifested by an conspicuous metamorphic jump to the both underlying and overlying complexes. Comparing to the Bôrka Nappe the olistoliths in the Meliaticum s.s. consists of non-metamorphous and/or by slightly metamorphous rocks (excepting light crystalline limestones) with higher abundance of deep-water deposits (radiolarites). From this reason it is probable that the Meliaticum s.s. represents shallower and likely also younger parts of accretionary prism which did not reach stronger HP/LT metamorphism as it was in case of the rocks of Hačava sequence.

Tectonics

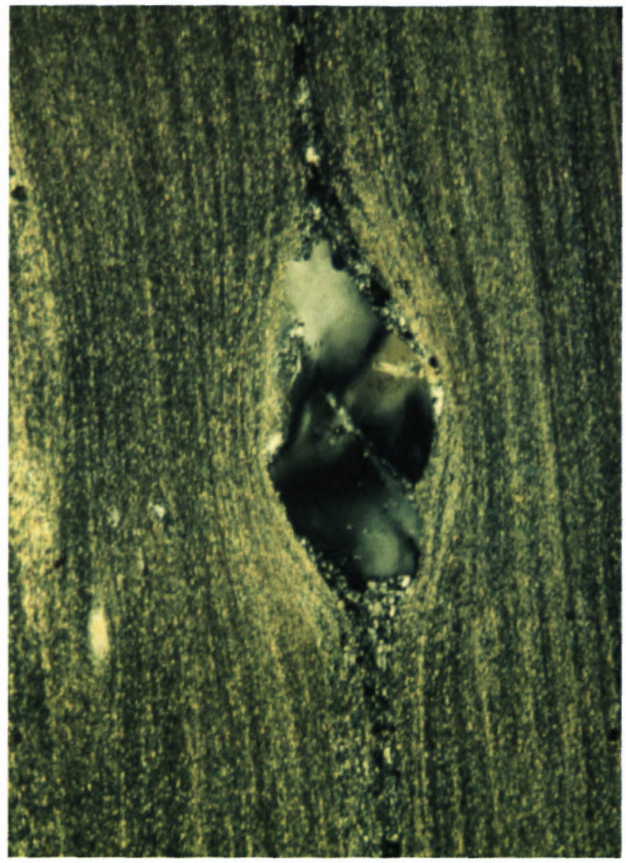
The Bôrka Nappe bears traces of deformation and metamorphism in condition of high pressure and low temperature, i.e. the nappe or at least its parts, had to occur in relatively deeper parts of subduction zone for a certain period. Basically, it is a remnant of a subduction-accretionary complex containing abundant blocks resembling the Late Paleozoic rocks of Gemericum and Mesozoic rocks of Meliaticum.

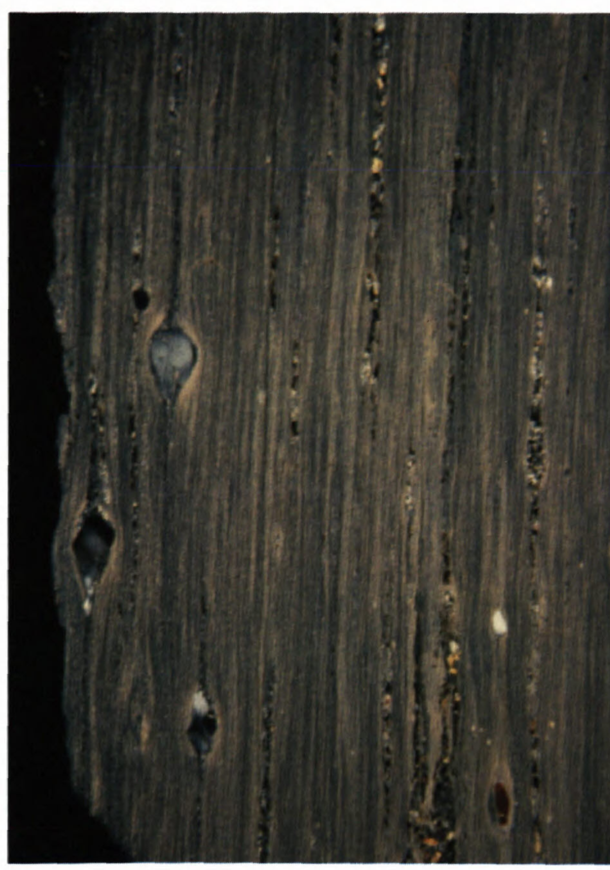
Petrological characteristics of the metabasics and metapelites of the Bôrka Nappe indicates polymetamorphic evolution with the first HP/LT degree (P > 1.3 Gpa, T ~ 500 degrees C) and with the second LP degree (P ~ 0.5 Gpa, T ~ 400 degree C). The PT path corresponds to the model of ocean crust subduction followed by fast isothermal decompression (Mazzoli & Vozárová 1998).

The Bôrka Nappe is a tectonic unit with a very complicated internal structure reflecting complicated tectonic history during the formation of its lithology (pre-rift and rift stages) and also during the orogenic stages (subduction-accretionary, collisional, transpression-transtensionary). It is interpreted as out-of-sequence nappe overthrusted during the collisional (transpression) stage on the Gemericum from south. Its today's occurrences are almost exclusively restricted to the areas north of Rožňava fault zone. Almost in all occurrences it tectonically overlies the rocks of Early and Late Paleozoic of Gemericum (Gelnica and Gočaltovo Groups). It does not form continual nappe body but only larger or smaller erosively or tectonically separated nappe fragments with imbricated internal structure.

The palaeotectonic and palaeofacial studies suggest that in the Late Paleozoic and probably also in the Mesozoic the depositional area of rock sequences of Bôrka Nappe represented a continuation of the Southern Gemericum sequence depositional area. Their characteristic feature is higher degree of metamorphism comparing to rocks of underlying and overlying units. This metamorphism is connected with subduction-accretionary process related to the gradual closure of the Meliata-Hallstatt extremity of the Kimmeridgian ocean. The radiometric datings Ar39/Ar40 performed on fengite (Maluski et al. 1993, Faryad & Henjes-Kunst 1995, 1997 Dallmeyer et al. 1996,) suggest that uplift through isotherm 350 – 400 degrees C occurred in the Late Jurassic (165 – 150 Ma) confirming the Kimmeridgian age of the tectono-metamorphic processes connected with the origin of high-pressure mineral associations. The metamorphic conditions reached by rocks during subduction (~500^0 C and ›13 Gpa) corresponds to the depths of about 40-50 km in the stability area of the blue schist epidote subfacies. The metamorphic evolution coincidies to a complicated deformation evolution certainly more complicated than in other tectonic units of the West Carpathians. However, the kinematics of movements has not yet been unambiguously reconstructed.

Present occurences of the Bôrka Nappe do not coincide with the former suture zone after the ocean closure. They are in alochthonous position to which they were moved after the HP/LT metamorphism and exhumation. A conspicuous metamorphic jump of the Bôrka Nappe rocks comparing to the overlying (Silicicum and Turnaicum) and underlying (Gemericum) rocks in the recent geologic structure suggests an important role of younger tectonic processes and tectonic transport to the present position after the high-pressure metamorphism.



Paleogeographic and paleotectonic evolution - a discussion

Several rather different paleofacial, paleotectonic and paleogeographic reconstructions of the Meliaticum sedimentation basin and ideas on its relation to sedimentation areas of the adjacent tectonic units have been published. Several geodynamic models were suggested recently as well. These reconstructions and geodynamic models are rather variable and in some cases even contradictory. They are commonly not supported by a complex analysis of the all available geological data, including field evidence and they are often based on rather limited information.

Such fundamental questions as a location of the subduction zone and a suture after the "Meliata ocean" closure, similarly as the dip direction of the suture remain unsolved or at least insufficently proved. An idea about the southern dip of the suture, similar to the dip of the younger Alpine sutures resulting from the closure of the depositional basins of the Western Carpathian tectonic units, is generally accepted, though without unambiguous evidence. The present location of the Bôrka nappe occurrences is impossible to associate with a position of the original suture formed by the closure of the "Meliata ocean". All occurrences are in allochthonous position to which they were displaced after the HP/LT metamorphism and exhumation.

Conclusion

The HP/LT metamorphosed rocks along the southern margin of the Gemer zone (Jasov, Šugov Valley, Hačava, Bôrka - Lúčka and numerous occurrences in the Nižná Slaná Village depression) are assigned to a single tectonic unit termed as the Bôka Nappe.

The Bôka Nappe structurally represents the lowermost tectonic unit in a complicated geological structure formed by a pile of several allochthonous units overlying Gemericum. It is interpreted as out-of-sequence nappe overthrusted from the south during a collisional (transpressional) stage of the Alpine orogeny. Most of its superficial occurrences are north of the Rožňava fault zone. Almost at all localities it tectonically overlies the Late Paleozoic rocks of the Gemericum (Gočaltovo Group). It is tectonically overlain by the Turna Nappe or directly by the Silica Nappe.

The Bôrka Nappe does not form a continual nappe body and consists of numerous larger or smaller erosionally and tectonically separated nappe fragments. They have complicated imbricate internal structure consisting of the Late Paleozoic (Permian) and Triassic - ?Jurassic sequences. The Late Paleozoic part (Jasov and Bučina Formations) is lithofacially well correlated with the lower part of the Gočaltovo Group of Gemeric Unit.

Paleotectonic and paleofacial reconstructions show that during the Late Paleozoic and probably also in the Mesozoic time depositional area of the rock sequences of the Bôrka Nappe was adjacent to the Gemericum.

The relation of the HP/LT metamorphism of the Bôrka nappe rock sequences to the subduction - accretion processes along the Meliata ocean margin is generally accepted.

Numerous ideas concerning location of the subduction zone during the closure of the Meliata ocean, timing of the subduction mechanism commencement and also the dip direction of the assumed subduction zone are rather speculative. Generally a southern dip of the subduction zone is considered but scattered kinematic indicators of ductile deformation related to the crystallisation of HP/LT minerals offers possibility of the opposite (northern) dip of the subduction zone as well.

40Ar/39Ar mineral dating on fengite shows the Late Jurassic cooling age (165 - 150 Ma). PT-conditions of the metamorphic peak (550 - 500^0 C and 12 - 2 kbar) suggest at least 40 km depth of subduction responding to the stability zone of the epidote subfacies of the blueschists facies. Preservation of the high-pressure mineral assemblage is due to a very rapid uplift of the subducted rocks.

Conspicuous differences in character and degree of metamorphism between rock sequences of the Bôrka Nappe and underlying (Gemericum) and overlying (Turna Nappe, Silica Nappe) tectonic units point to their post-metamorphic tectonic convergence.

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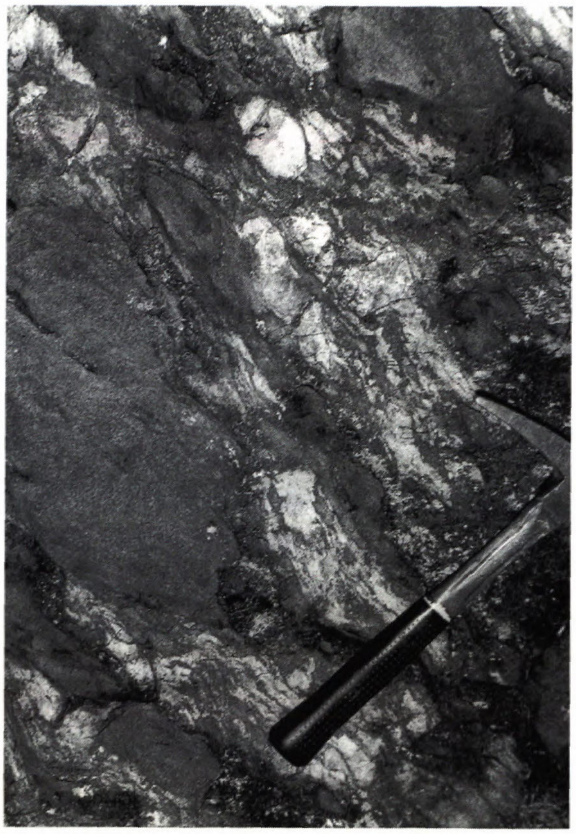
PLATE I

Fig. 1: Banded marble of the Dúbrava Formation (the Bôrka Nappe) in abandoned quarry about 1 km south of the Markuška village (7 km NNW of the Štítnik town). Photo P. Reichwalder.

Fig. 2: Intensely folded layers of the metabasalt volcanoclastics in marbles of the Dúbrava Formation (the Bôrka Nappe). Locality and photo as Fig. 1.

Fig. 3: Thin section of the metarhyolite of the Bučina Formation (the Bôrka Nappe) with strong linear elongation (stretching lineation) of the quartz and feldspar porphyroclasts from the Spúšťadlo Hill, 5 km S of the Dobšiná town. Photo L. Osvald.

Fig. 4: Detail of the stretched quartz porphyroclast (the length of porphyroclast about 1 mm) in the metarhyolite of the Bučina Formation of the Bôrka Nappe from the Spúšťadlo Hill, 5 km S of the Dobšiná town. Photo L. Osvald.



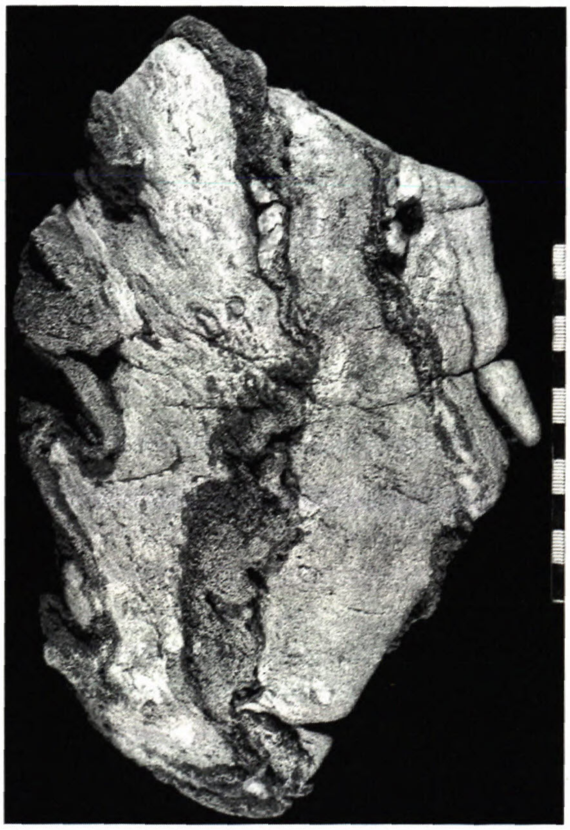


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PLATE II

Fig. 1: Two generations of mesoscopic folds in a layer of the metabasic volcanoclastics in the marble of the Dúbrava Formation (the Bôrka Nappe) in the Šugov valley, 3 km SSW of the Medzev town. Limbs of the older recumbent are refolded by a younger system of asymetric overturned to isoclinal folds.

Fig. 2: Banded glaucophanite of the Dúbrava Formation of the Bôrka nappe with assymetrically folded metamorphic banding at the southern slope of the Radzim Hill, 5 km SSW of the Dobšiná town.

Fig. 3 and 4: Details of the metabasalt (glaucophanite) fragments, their deformation and relation to the marble matrix of the Dúbrava Formation (the Bôrka Nappe) in the Šugov Valley, 3 km SSW of the Medzev town.

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Inner structure of Hronicum

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Abstract. The inner structure of Hronicum has been documented in Chočské vrchy Mts., Nízke Tatry Mts. and Malá Fatra Mts. The transport direction of Hronicum partial nappes has a NW orientation in these mountains. In order to determine original spatial arrangement of nappe bodies of Hronicum the palaoegeographic situation in Triassic was used. We understand the depositional environment in this system as a system of carbonate platforms and intraplatform basins, which were structured into individual subordinate nappes during the Hronicum displacement.

Key words: West Carpathians, nappe tectonics, Hronicum, palaeogeography

Introduction

A basic structure of the West Carpathians is a nappe structure consisting of Paleozoic (possibly also of pre-Cambrian) to Tertiary rock complexes (Uhlig 1907, Andrusov et al. 1973). The Central West Carpathians and Inner Carpathians occur in the south and the Outer Carpathians separated by Klippen Belt occur in the north (Matějka & Andrusov 1931, Andrusov et al. 1973). The pre-Senonian nappe structure consists of nappe systems of two categories (Biely & Fusán 1967). The first one is composed of pre-Late Carboniferous fundament and normally overlying Late Paleozoic and Mesozoic. The second category is represented by rootless nappes consisting of Mesozoic, occasionally also of Late Paleozoic which entirely lost connection with their basement (Andrusov et al. 1973, Mello in Gregor et al. 1976, Mello & Polák 1978). The nappe system of Hronicum is assigned to the second type of category.

Hronicum was defined by Andrusov, Bystrický and Fusán (1973). According to their definition it consists of two facial areas (Čierny Váh and Biely Váh area) and of two wide-spread nappes (lower Šturec and upper Choč nappes). The authors identified the Šturec nappe with the Čierny Váh facial area and the Choč nappe with Biely Váh facial area. The Hronicum is formed by bed succession ranging from Carboniferous to Neocomian. On the basis of the latest research the Hronicum represents a system of subordinate nappes. It occurs in a form of more blocks individualized either by erosion or tectonically (Fig. 1).

Methodology

In the paper we document division of Hronicum into a system of nappes and we defined a direction of tectonic transport of subordinate nappes in Malá Fatra Mts., Low Tatras and Chočske vrchy Mts. The structural study includes interpretation of mesoscopic indications of ductile deformation. We processed statistically fold axis orientations, bedding plane orientations and constructional β-axes orientation of flexures and/or direction of β-axes of folds of Hronicum subordinate nappes.

In order to determine spatial relationships of Hronicum partial nappes we used the palaeogeographic situation during Triassic. The characteristics of the Triassic depositional environment have been chosen according to the fact that Hronicum nappes are to a great extent composed of Triassic rocks.

Nappe system of Hronicum

Hronicum represents a system of imbricated nappes of which spatial connection among individual mountains is often problematic. The nappes are mainly composed of Triassic members, Late Paleozoic and locally preserved Jurassic-Cretaceous formations sporadically occurring in some of them. Termination of deposition in the Early Cretaceous (Hauterive) dates the commencement of the tectonic transport.

We understand the depositional environment of Hronicum in the Triassic (Late Pelsonian - Early Tuvalian) as a system of carbonate platforms and intraplatforms basins (Fig. 2). On the basis of facial analysis it is possible to divide two basins and two carbonate platforms (from the northwest to the southeast) - Dobrá Voda Basin, carbonate platform of so called upper nappe, Biely Váh Basin and Čierny Váh carbonate platform. The palaeogeographic position of the last one carbonate platform has not yet been satisfactory solved (Havrila, 1993). We can identify both intraplatform basins, which have not probably been interconnected, with the Biely Váh facial area on the basis of lithologic content. Similarly we can identify both carbonate platforms with Čierny Váh facial area.

Čierny Váh facial area is characterized by a sequence of carbonate platform which is represented by a succession: Ramsau dolomite; laterally interfingering Wetterstein

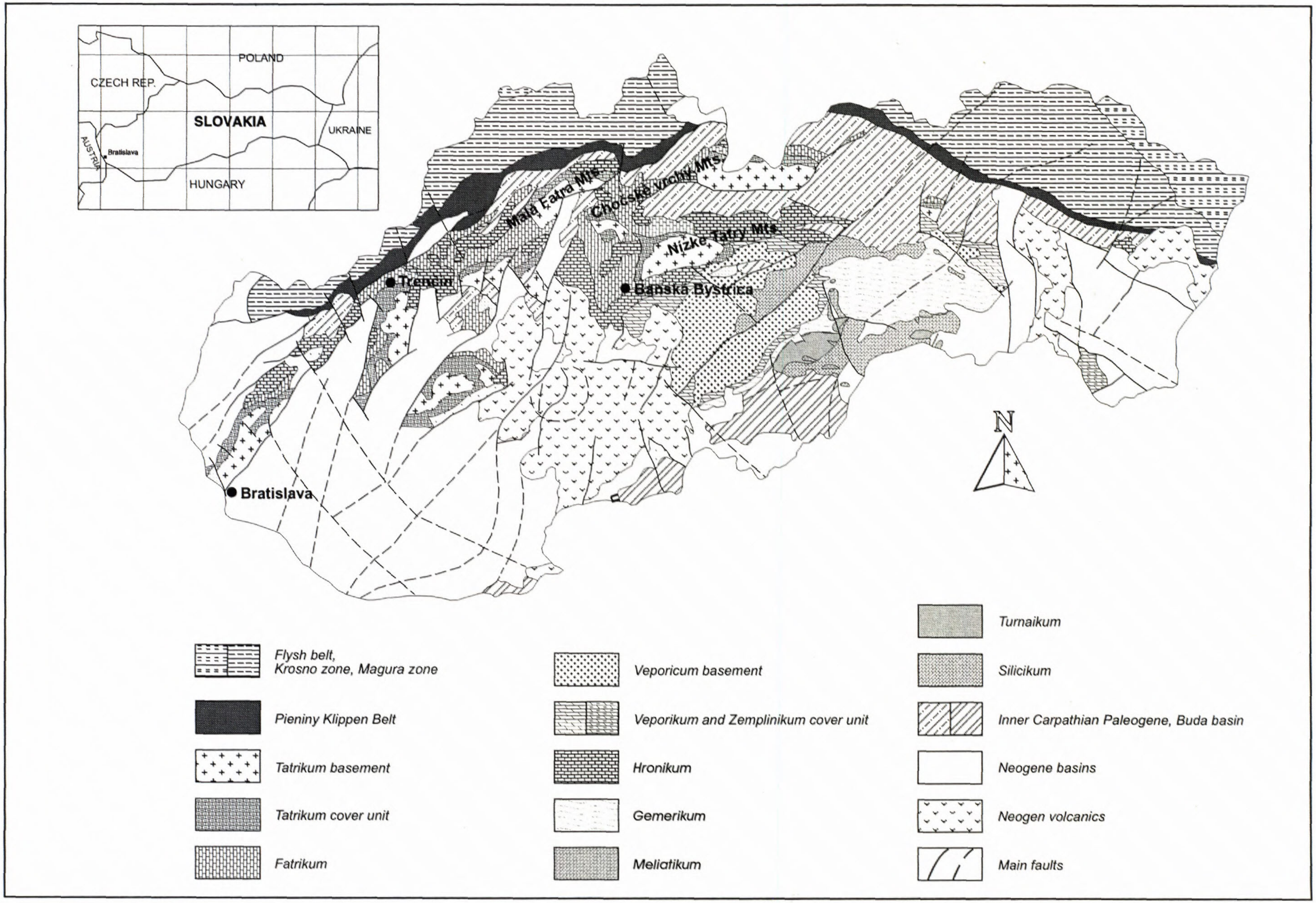

Fig. 1 Tectonic sketch of the Slovak part of West Carpathians

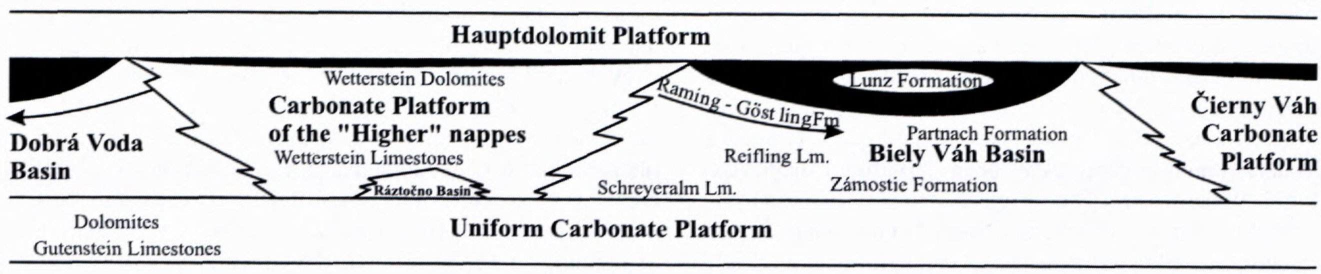

Fig. 2 The inferred original distribution of Triassic rocks across the Hronicum sedimentary area

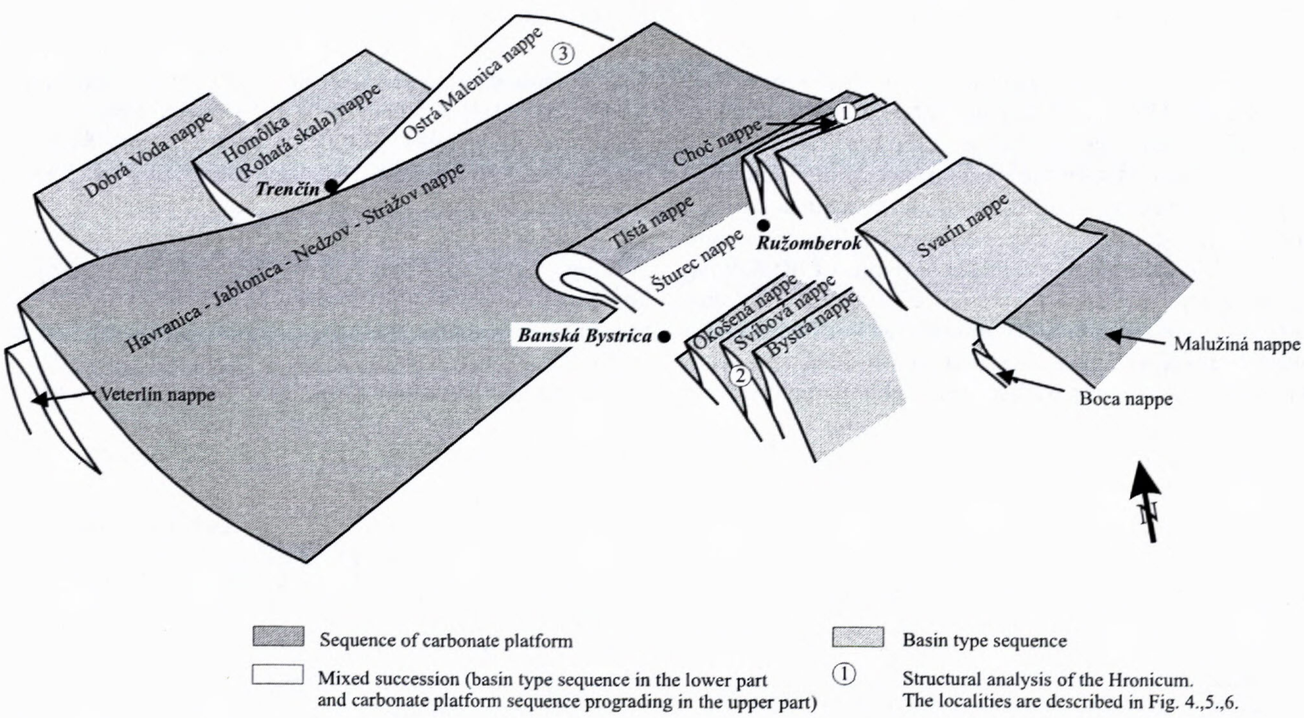

Fig. 3 Nappe system of Hronicum

limestones and dolomites comprising a margin of a platform; thin layer of Lunz beds. Biely Váh facial area is characterized by a basin type sequence, represented by a succession of lithostratigraphic units: Farkašovce breccias, Zámostie limestones, Reifling dolomites, Reifling limestones, Schreyeralm limestones, Partnach Member, Raming limestones, Göstling limestone, Aon shales, Korytnica limestone, Lunz Member. The boundary between the basic facies is represented by mixed succession consisting of basin type sequence in the lower part and carbonate platform sequence prograding over the basin succession in the upper part.

Triassic of Hronicum has three evolution stages: 1) Uniform Middle Triassic carbonate ramp underlies both successions 2) The above mentioned basic successions are capped by Lunz Member even if differently thick. They fill basin depressions and they are not present or they only reach a small thickness above carbonate platforms. It proves together with the occurrence of Raming-Göstling turbidite limestones, located along carbonate platform margin, lateral position of both basic types of Hronicum (Havrila in Gross et al., 1993, Havrila 1993). The Triassic evolution is terminated by a carbonate platform of the Hauptdolomit.

The displacement of the nappe body of Hronicum from its depositional environment occurred during the Cretaceous deformation of the Carpathian orogen (Andrusov et al. 1973, Bystrický 1973). The thrust plane did not follow the same stratigraphic level. As a result of an oblique cut of individual lithostratigraphic members Mesozoic complexes consisting mainly of carbonate members occur in the frontal part of the Hronicum nappe. They were separated from their Late Paleozoic basement along horizons of clayey Lower Triassic shales. Backward the subordinate nappes of Hronicum also contain Late Paleozoic members.

During the Hronicum displacement a desintegration of an originaly uniform body into a system of subordinate nappes occurred (Fig. 3). Their structural - tectonic position within the framework of the Hronicum nappe system is controlled on the basis of sedimentological and facial characteristics. The Dobrá Voda nappe and Homôlka (Rohatá skala) nappe have been structured from the Dobrá Voda Basin. The original depositional environment of the nappes of Veterlin, Ostrá Malenica and Šturec was situated on the boundary between carbonate platform and basin. The Triassic members of so called upper nappes (Havran, Jablonica, Nedzov and Strážov nappes) and nappe of Tlstá indicate depositional environment of carbonate platform. Biely Váh Basin was a depositional environment of a nappe system distinct in the whole Chočské vrchy Mts., Pohronie and Považie.

The inner structure of the Hronicum and the tectonic transport direction were analysed in Chočské vrchy Mts., Nízke Tatry Mts. and Malá Fatra Mts. Hronicum is represented by a basin type sequence in the eastern part of the Chočské vrchy Mts. In the western part of the mountains it is represented by a carbonate platform sequence with a stratigraphic span from the lowermost Middle Triassic to Norian. The deformation of basal horizons of the moving nappe is indicated by an occurrence of tectonic breccias on the overthrust plain of tectonic outliers of Hronicum in the western part of the Chočské vrchy Mts. The Hronicum nappe system is composed of three subhorizontally lying slab bodies with analogous bed succession. Lithological character of the Middle Triassic members belonging to the bed succession of the lower two tectonic bodies shows their original location in the marginal part of the Biely Váh Basin nearby its contact with carbonate platform. It is evidenced by outcropping of the proximal members of Raming- Göstling turbidite system. The placement of the upper subordinate nappe was basinward of the carbonate platform and it is documented by the occurrence of distal members of Raming- Göstling turbidite system and Partnach Formation. Statistic evaluation shows slight bending of bedding planes in the NE-SW direction in the lower and upper subordinate nappes (Fig. 4). It suggests NW-SE direction of tectonic transport. During the displacement of the Hronicum nappe a development of imbricated structure without distinct fold structures took part in the area of today's Chočské vrchy Mts.

On the southern slopes of the Nízke Tatry Mts. in the area of Lopej valley and adjacent Bystrá foreland three partial Hronicum nappes of local extent occur (Matějka & Andrusov 1931, Kettner 1940, 1958, Biely 1963). They overthrust each other (Fig. 5) - Bystrá nappe, Svibová nappe, Okošená nappe (Biely et al. 1988, Biely et al. 1997). Their stratigraphic span is Permian - Late Triassic.

Biely (1963) explains the genesis of subordinate nappes by cleaving of a uniform nappe slab by a reverse dis placement with south vergency. Later he considers a system of Hronicum nappes in this area as a pre-Gosau having a northern vergency (Biely et al. 1998). Similarly this same interpretation he applies for the northern side of Low Tatras where three subordinate nappes of Hronicum (Boca, Malužiná and Svarín) occur. He does not term

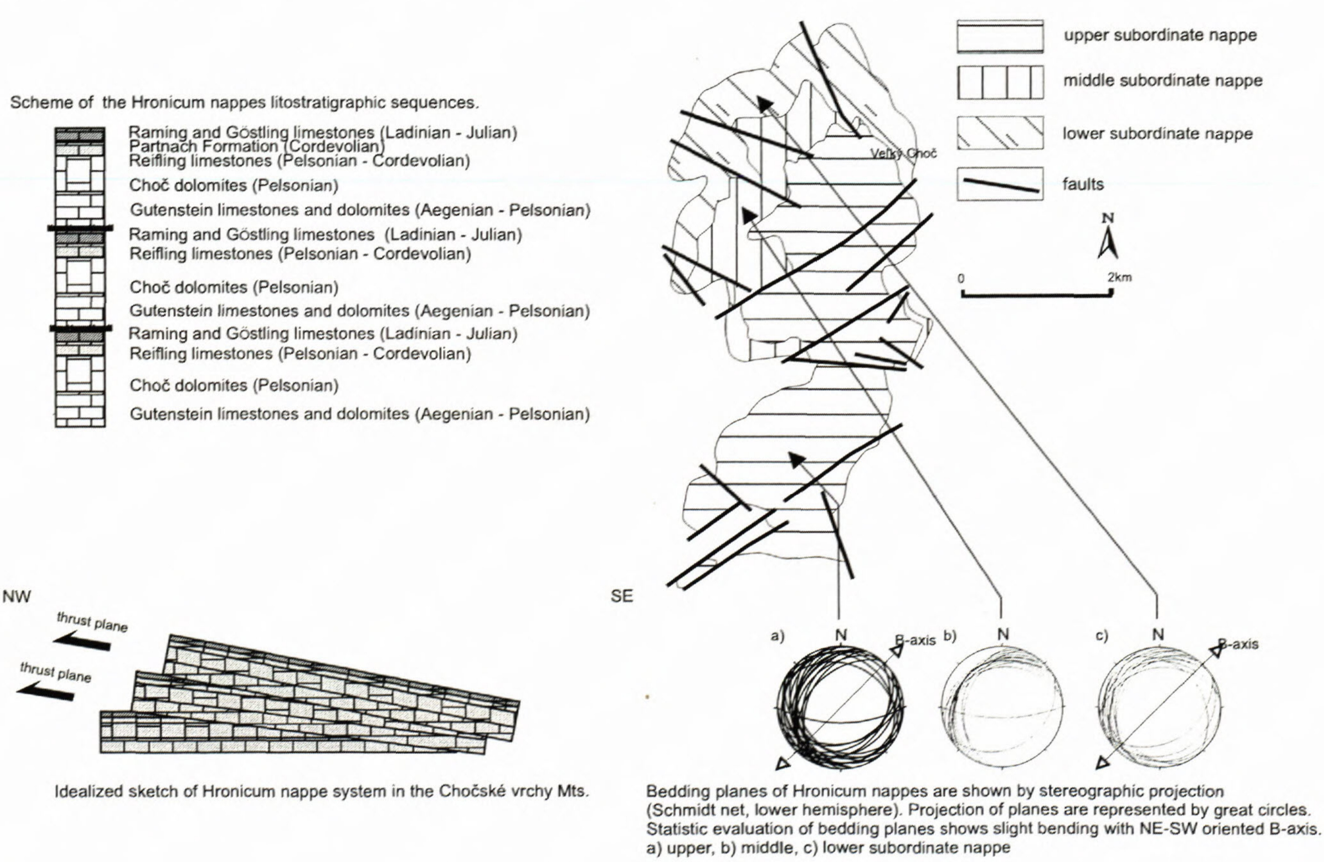

Fig. 4 The Hronicum nappe system in Chočské vrchy Mts.

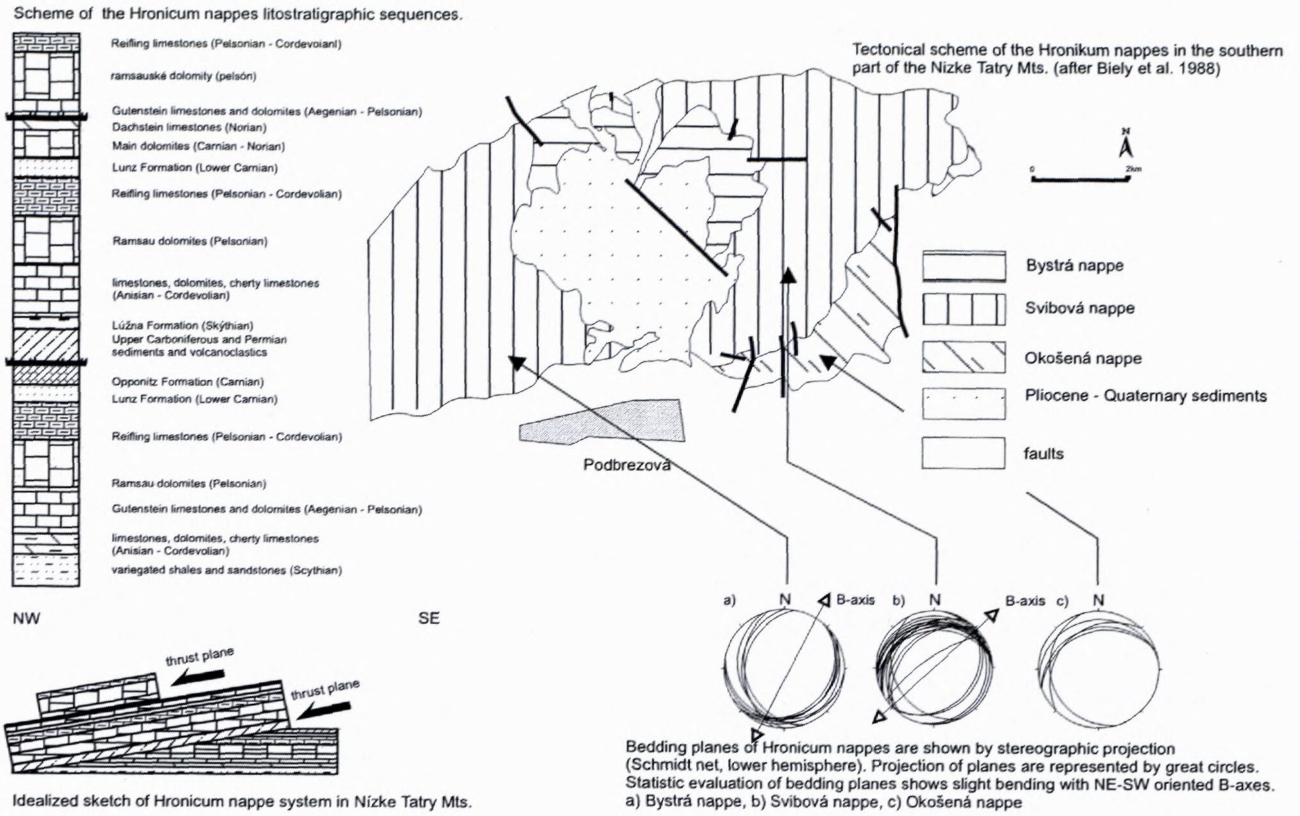

Fig. 5 The Hronicum nappe system in southern part of the Nízke Tatry Mts.

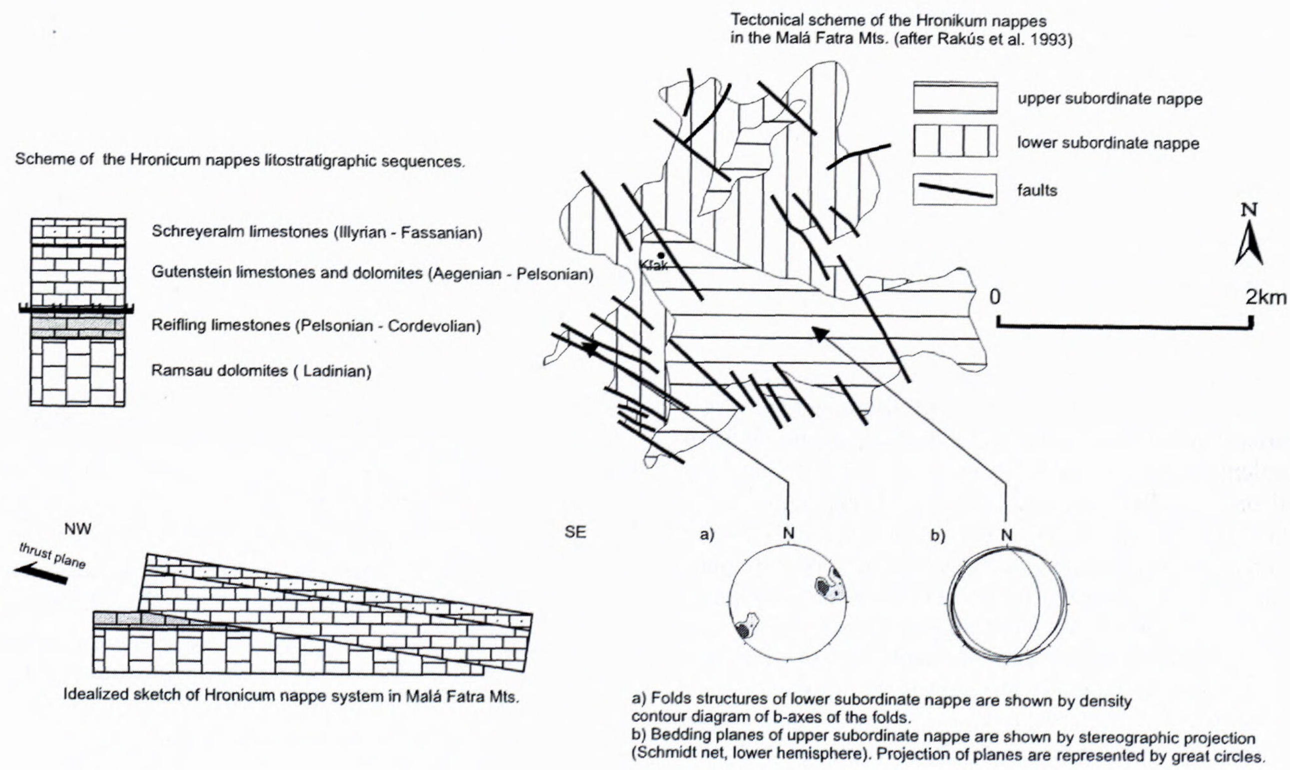

Fig. 6 The Hronicum nappe system in Malá Fatra Mts.

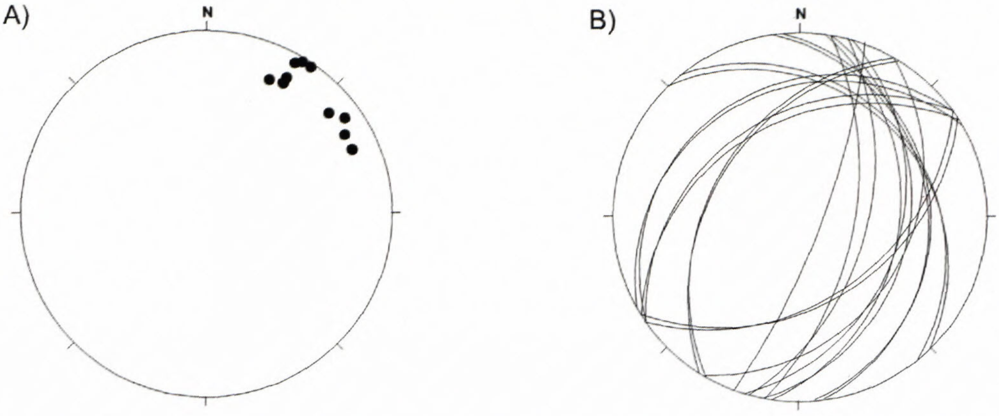

Fig. 7A Orientation of folds structures from abandoned quarry near village Turie is shown by β-axes of the folds, Fig.7B Bedding planes are shown by stereographic projection (Schmidt net, lower hemisphere). Projection of planes are represented by great circles

anyone of the subordinate nappes in the area of Lopejská valley and Bystrá foreland as Choč nappe, but he does not exclude that some of them originally formed together with an outlier comprising Veľký Choč, an uniform body. The Triassic of Hronicum subordinate nappes on the southern slopes of Low Tatras consists of basin type sequence while individual tectonic bodies comprise flat bent slabs which frequently are strongly broken. Palaeogeographically they were located in the central part of the Biely Váh Basin. Structural analysis of bedding planes documents a slight refolding with NE-SW orientation of b-axis in the upper and middle partial thrust sheet (Fig. 5).

A complicated inner structure of the Hronicum is documented by folds in nappe outlier of Kľak (Fig. 6) and by an abandoned quarry nearby village Turie (Fig. 7) in the Malá Fatra Mts. Orientation of b-fold axes shows orientation of tectonic transport from SE to NW. According to the occurrence of Schreyeralm limestones in the bed sequence of the upper subordinate nappe we assume its palaeogeographic position on the basin margin. Today we are not able to identify whether it was Dobrá Voda Basin or Čierny Váh Basin.

Conclusion

Hronicum represents a system of imbricated subordinate nappes. They occur in a form of nappe outliers which spatial connectivity among individual mountains is often problematic. They mainly consist of Triassic members and only locally preserved Jurassic - Cretaceous formations. The original deposition environment of Hronicum in Triassic we understand as a system of carbonate platforms and intraplatform basins - Dobrá Voda Basin, carbonate platform of so called upper nappes, Biely Váh Basin and carbonate platform of Čierny Váh, which comprises individual subordinate nappes of Hronicum. The inner structure of Hronicum indicates generally consistent direction of movement of its nappe segments. The tectonic transport of subordinate nappes of Hronicum in the area of Malá Fatra Mts., Nízke Tatry Mts. and in the area of Chočske vrchy Mts. is toward northwest.

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Marginal and deep-sea deposits of Central-Carpathian Paleogene Basin, Spišská Magura region, Slovakia: Implication for basin history

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Abstract. The sedimentary fill of the Central-Carpathian Paleogene Basin (CCP Basin) in the area of the Spišská Magura region consists of Bartonian to Early Rupelian marginal and deep-water deposits. The marginal deposits are composed of breccias, conglomerates, nummulitic sandstones and limestones representing a transgressive systems tract. They are overlain by conglomerates and sandstones, shales with thick conglomerate and sandstone beds (deposits of lowstand systems tract) which, in turn, are overlain by shales containing thin sandstone and occasional conglomerate beds belonging to transgressive systems tract. The whole sedimentary succession is capped by alternating shale and sandstone beds of basin axial turbidite system deposited during lowstand of relative sea level. The main factor governing deposition in the region is tectonics, which determines the shelf width, slope gradient and sediment input.

Key words: Central-Carpathian Paleogene Basin, deep-water deposits, systems tract, sea level, tectonics

Introduction

The fill of deep-marine basins rarely consists of single type of depositional system. Controls influencing development of a deep-water system like rate, type and source of sediment supply, regional basin tectonics and sea level, usually change during a basin history. This is particularly valid for basins in an active tectonic setting where source areas, accommodation space and slope gradients may change very abruptly and thus affect type of depositional systems. The analysis of individual systems during the basin history is of main importance - it helps to understand distribution, connectivity, continuity and facies character of potential hydrocarbon reservoirs and to predict the most perspective hydrocarbon prospects.

The relatively small deformation of deposits, good outcrops and abundance of boreholes in the Central-Carpathian Paleogene Basin (CCP Basin, Fig. 1) provide an opportunity to study sediments of individual depositional systems evolving during the basin history. The thick sedimentary succession in the northern, Spišská Magura part of the CCP Basin, records deposition from initial transgression to deep-marine sedimentation. It resembles successions known from the entire northern and eastern part of the basin (Podhale, Spiš, Levoča and Šariš regions, Fig. 1), however, some sedimentary features show deposition in unique subenvironments within the basin which makes it important for understanding basin history. The main objective of the paper is to describe Paleogene deposits, their vertical and lateral facies successions (facies tracts of Mutti 1992) in the Spišská Magura part of the CCP Basin and to draw implications for the basin history based on these successions.

Geological setting

The CCP Basin lies in the northern part of the Slovakian Inner West Carpathians (Fig. 1). To the south it is bounded by the pre-Paleogene, Mesozoic and Paleozoic formations of the Inner West Carpathians. In the north it is separated from the Outer-Carpathian Flysch zone by the Pieniny Klippen Belt. The basin is developed in a forearc position on the proximal part of the accretionary wedge above the southwestward subducting oceanic slab attached to the European Platform. The kinematic history of the basin is mostly explained as a result of the escape tectonics of the North-Pannonian unit caused by the oblique subduction of the oceanic crust of the Outer Carpathian Flysch trough beneath the North-Pannonian unit (Csontos et al. 1992). However, the subduction is not proved directly, the volcanic arc is not developed and there is only minor evidence about ultrabasic rocks (Soták, Bebej & Biroň 1996) of uncertain origin (in situ? redeposited?) in the CCP Basin fill. The tectonics and sediments of the basin suggest a complex kinematic history with prevailing extensional regime and minor compression mostly occurring along the Pieniny Klippen belt. The elongated, crescent-shaped basin is about 200 km long; the maximum width is about 60 km. The northernmost part of the basin extends to the Poland where it is called the Podhale Basin (Fig. 1). The basin deposits of subaerial and marine origin with stratigraphic range Paleocene – earliest Miocene (Egerian) reach thickness around 4 000 m. The sedimentologic investigations (e.g. Marschalko 1964, 1968, 1978, 1982) resulted in a concept of prevailing deep-water deposition by turbidity flows during the basin history. Some authors divide the basin fill into two sedimentary cycles (e.g. Rudinec 1989). The lower cycle is represented by shallow-marine transgressive deposits and deep-water dark shales also called „subflysch deposits" (Borové Fm. and Huty Fm. of Gross, Köhler & Samuel 1984). The upper cycle is represented by sandy turbidites (Zuberec Fm. and Biely Potok Fm. of Gross, Köhler & Samuel 1984).

The lower cycle deposits originated during initial transgression from NW and N and following abrupt deepening (collapse) of the basin causing deposition in a deep, anoxic environment (Gross et al. 1980, Baráth et al 1997, Buček et al. 1998). The pelagic deposits, condensed deposits expressed by manganese beds in the Poprad Depression, and "menilite-like" deposits have been thought

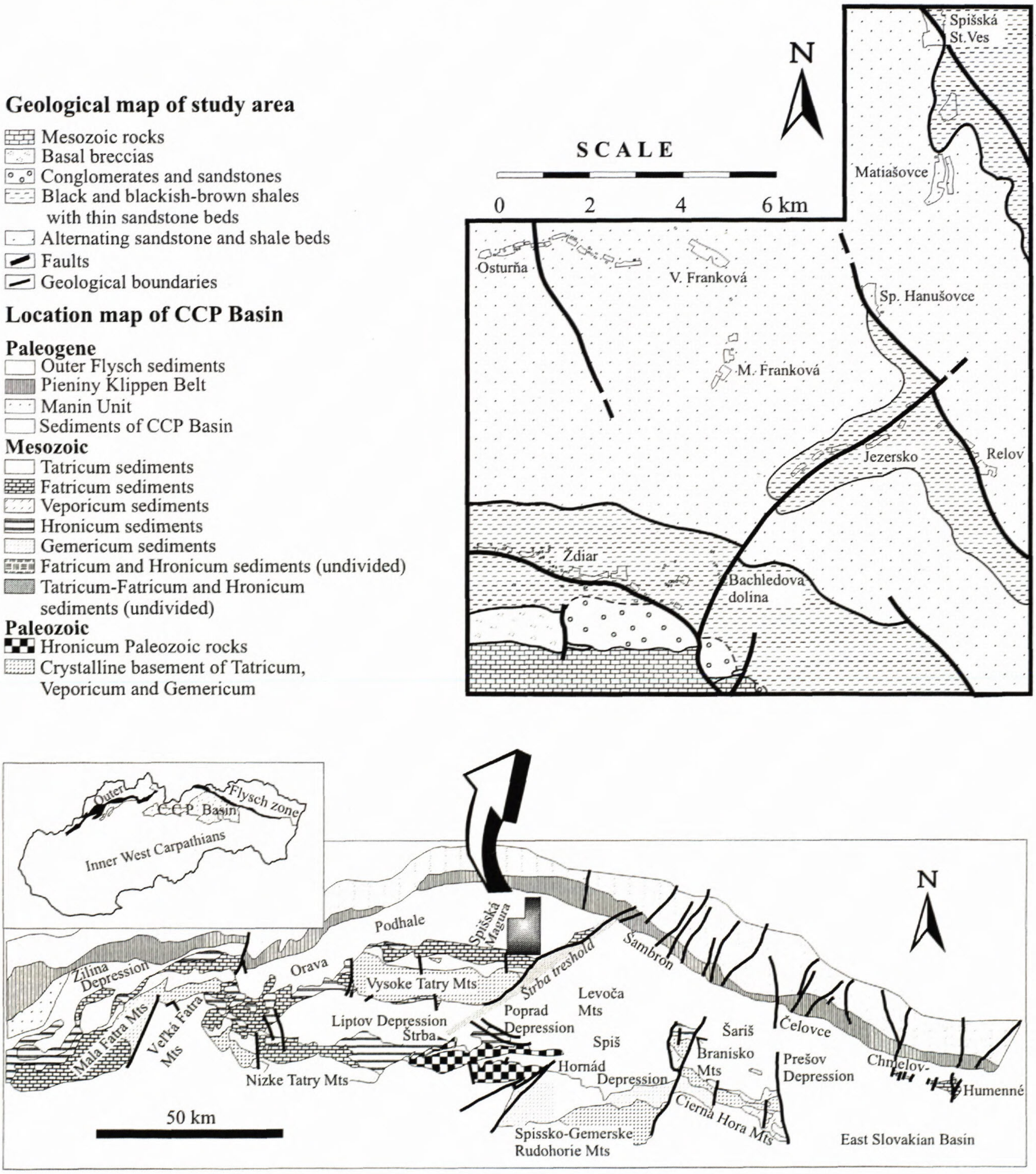

Fig 1: Location map of the study area also showing the position of the CCP Basin in the West Carpathian system and individual parts of the basin.

to record deposition during sea level rise and highstand. The collapse also caused a deposition of "muddy turbidites, flysch sediments and scarp breccias" in the Šambron Depression nearby the Pieniny Klippen Belt (Baráth et al. 1997, Fig. 1). The upper sedimentary cycle of the Central-Carpathian Paleogene Basin is supposed to be developed during the lowstand as a prograding lowstand wedge with a complex deep-sea fan zones (Baráth et al. 1997). On the basis of opposite palaoeflow directions in the deposits of the upper sedimentary cycle, two main depositional systems entering the basin from the west and south-east have been assumed. These systems should merge together in the area of Spiš and Poprad Depressions. The area was interpreted as the deepest part of the basin (Marschalko & Radomski 1960). However, our research suggests division of the basin into two basic subbasins separated by a submarine elevation trending in NE-SW direction and consisting of Štrba treshold and Ružbachy elevation (Janočko et al. 1998). Although the tectonic development of the subbasins was similar, each basin has its own depositional systems and own sedimentary history. The fans developed along the basin axis, however, the lateral sediment input into the basin was also described (e.g. Marschalko 1964, Westwalewicz-Mogilska 1986, Wieczorek 1989). In the studied area the deposits laterally entering the basin are represented by breccias, conglomerates and sandstones described as basin marginal facies (Marschalko & Radomski 1960) or Tokáreň Fan (Westwalewicz-Mogilska 1986).

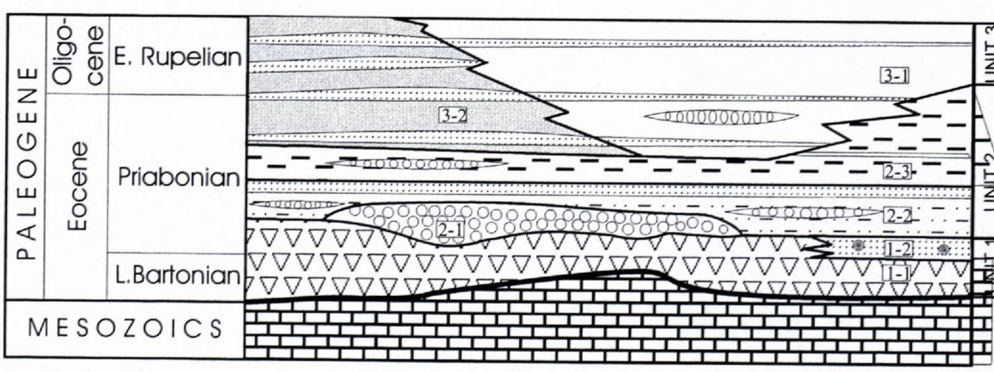

Fig. 2: Stratigraphy of the deposits in the studied area. According to Gross, Köhler & Samuel (1984) the unit 1 deposits represent Borové Fm., unit 2 deposits represent Huty Fm. and unit 3 deposits represent Zuberec Fm. The units 1 and 2 are sometimes defined as lower sedimentary cycle, the unit 3 is refferred to the upper sedimentary cycle. TST are represented by unit 1 and subunits 2-3, subunits 2-1, 2-2 and unit 3 compriese LST.

The studied area, occurring in the northern Slovak part of the CCP Basin, belongs to the Spišská Magura region (Fig. 1). The stratigraphy of this region consists of Mesozoic and Paleogene units (see Fig. 2). The pre-Paleogene units are represented by Mesozoic rocks of the Krížna nappe, cropping out in the western (Tatric) and middle (Ružbachy) parts of the region, and by the Mesozoic sequences of the Pieniny Klippen belt separating the region from the Outer Carpathian Flysch zone to the northwest. The Paleogene deposits (Fig. 2) consist of basal formation (Borové Fm. sensu Gross, Köhler & Samuel 1984) overlain by dark shales with minor sandstone and conglomerate beds (Huty Fm. of Gross, Köhler & Samuel 1984) and thick, laterally restricted body composed of poorly sorted conglomerates, mudstones and sandstones (Púcov Mb. of Gross, Köhler & Samuel 1984, Marschalko-Radomski 1960, Tokáreň Fan of Westwalewicz-Mogilska 1986). The whole Paleogene succession is capped by shales alternating with variable thick sandstones which are assumed to be a part of the basin upper sedimentary cycle by some authors (Zuberec Fm. of Gross, Köhler & Samuel 1984, Fig. 2).

Description of sedimentary successions

The post-Paleogene uplift of the Mesozoic and Paleozoic rocks of the High Tatras Mts. (ca. 15 Ma ago, Kráľ 1977, Fig. 1) also elevated the oldest, buried Paleogene deposits which now flank the slopes of the mountains. The profile from the mountains toward the deeper parts of the basin provides a complete section through the Paleogene sedimentary succession in the region. The sections obtained from outcrops were compared to archive boreholes penetrating the Paleogene succession. The thickness of the deposits in the studied area is about 1 600 m and it probably represents only a fragment of the original sedi mentary fill thickness. Based on clay mineral analysis and vitrinite reflectance data the postsedimentary uplift of at least 2 km is assumed in the area close to the Pieniny Klippen Belt in the northern part of the studied area (Milička 1998). This is supported by data from the Levoča Mts. located to the south of the studied area where a similar amount of uplift is suggested (Kotuľová, Biroň & Soták 1998).

The sedimentary succession was divided into three lithological units (Fig. 2).

Breccias, conglomerates, sandstones and sandy limestones comprise the base of the succession (unit 1). The age of the unit, determined by analysis of nummulite fauna, is the late Middle Eocene and Late Eocene (Late Bartonian and Priabonian, P14 – P15 zones of planktonic foraminifera, Janočko et al. 1998). The overlying deposits of unit 2 consist of three subunits: subunit 2-1 is composed of thick conglomerates filling an erosional scar cut into unit 1 and Mesozoic basement; subunit 2-2 consists of dark shales containing up to 5 m thick bodies of conglomerates and thick sandstone beds; and subunit 2-3 is composed of dark shales with minor thin sandstone and conglomerate beds. The uppermost unit 3 comprises alternating sandstones and dark shales. The analysis of nanoplankton and benthic foraminifera yielded the age ranging from the late Middle Eocene (Bartonian) to the lowermost Oligocene (Early Rupelian; NP zones 17 –21) for both units 2 and 3 (Janočko et al. 1998). Unit 2 contains redeposited large foraminifera of Early to Middle Priabonian age (P15 – P16 zones) and unit 3 contains redeposited large foraminifera of Early to Late Priabonian age (P16 – P17).

Unit 1

In the studied area unit 1 consists, from base to top, of two subunits represented by basal breccias, conglomerates and minor sandstones (subunit 1-1) and nummulitic sandstones and nummulitic sandy limestones (subunit 1-2). The maximum thickness of the unit is about 80 m but it is from a greater part reduced by erosion of the overlying subunit 2-1.

Fig. 3: Massive breccias of subunit 1-1 representing the basal Paleogene deposits in the studied region. The bar for scale is 2 m long.

The breccias of subunit 1-1 consists of angular dolomite and limestone clasts derived from the directly underlying Mesozoic basement. Massive, clast-supported structure prevails although minor layers of matrix-supported breccias also accur. The matrix is composed of poorly sorted silty sandstone occasionally containing fine pebbles. The clast size varies from a few centimeters up to 1 m. Internal organization is very poor, the clast orientation is random (Fig. 3) and it is mostly not possible to discern the individual beds. If the beds are observable, they are 1 to 2 m thick and have sharp base.

The breccias are overlain by massive, clast-supported conglomerates of subunit 1-1. The boundary between the breccias and conglomerates was not observed at any section and is not clear. The conglomerates consist of 1-15 cm angular, subangular and subrounded limestone and dolomite clasts. Locally it is possible to observe admixture of well-rounded quartz clasts having a size about 0.5 – 2 cm which comprises up to 10% of the sediment. Also redeposited tests of nummulites occur locally. The matrix consists of poorly sorted, medium- to coarse grained sandstone. The thickness of sharp and scoured based beds varies from 10 – 40 centimeters. The beds are separated by medium-grained, massive, parallel and cross-laminated sandstones comprising sharp-based beds up to 30 cm thick. The conglomerates and sandstones are often arranged into 6 – 8 m thick upward fining cycles. Amalgamation of beds can be locally observed.

Subunit 1-2 consists of sandstone, pebble sandstone and occasional sandy limestone containing nummulites. The boundary to the underlying basal breccias and conglomerates of subunit 1-1 is gradational. Sometimes the subunit directly overlies the Mesozoic limestone. The coarse-grained sandstone is massive, medium sorted and it contains nummulite tests and occasional angular and subangular pebbles of carbonates. Due to poor outcrops it is not possible to give more detailed characteristics of the subunit. The age, based on nummulite analyses (Janočko et al. 1998) varies from the Late Bartonian to the Priabonian (P 14 – P 15 zones of planktonic foraminifera).

Unit 2

Unit 2 consists of three subunits which are composed of thick conglomerate and sandstone body (subunit 2-1), dark and black shales alternating with thick conglomerate and sandstone beds (subunit 2-2) and dark and black shales with seldom thin conglomerate and sandstone beds (subunit 2-3, Fig. 2).

Subunit 2-1 consists of a thick conglomerate and sandstone body. Coarse-grained conglomerates and sandstones, reaching about 200 m thickness, overlie an erosional scar which cuts into the deposits of unit 1 or directly into the Mesozoic rocks. The vertical incision into the unit 1 is up to 60 m. The overall trend of sandstone occurrence in the subunit is increasing upward – in the lower part of the profile conglomerates prevail, in the uppermost part the conglomerates only form thin beds in sandstones (Fig. 4).

The conglomerates are mainly clast-supported and consist of angular and subangular clasts of Mesozoic carbonates (about 80%) and shales (1 – 2%), subrounded and well-rounded quartz clasts (about 10%), crystalline clasts (granitoids, melaphyres, cherts, 5%) and angular and subangular clasts of older Paleogene rocks (sandstones containing nummulites and bryozoa, conglomerates, dark shales, 3%). The sandstone and sandy limestone clasts

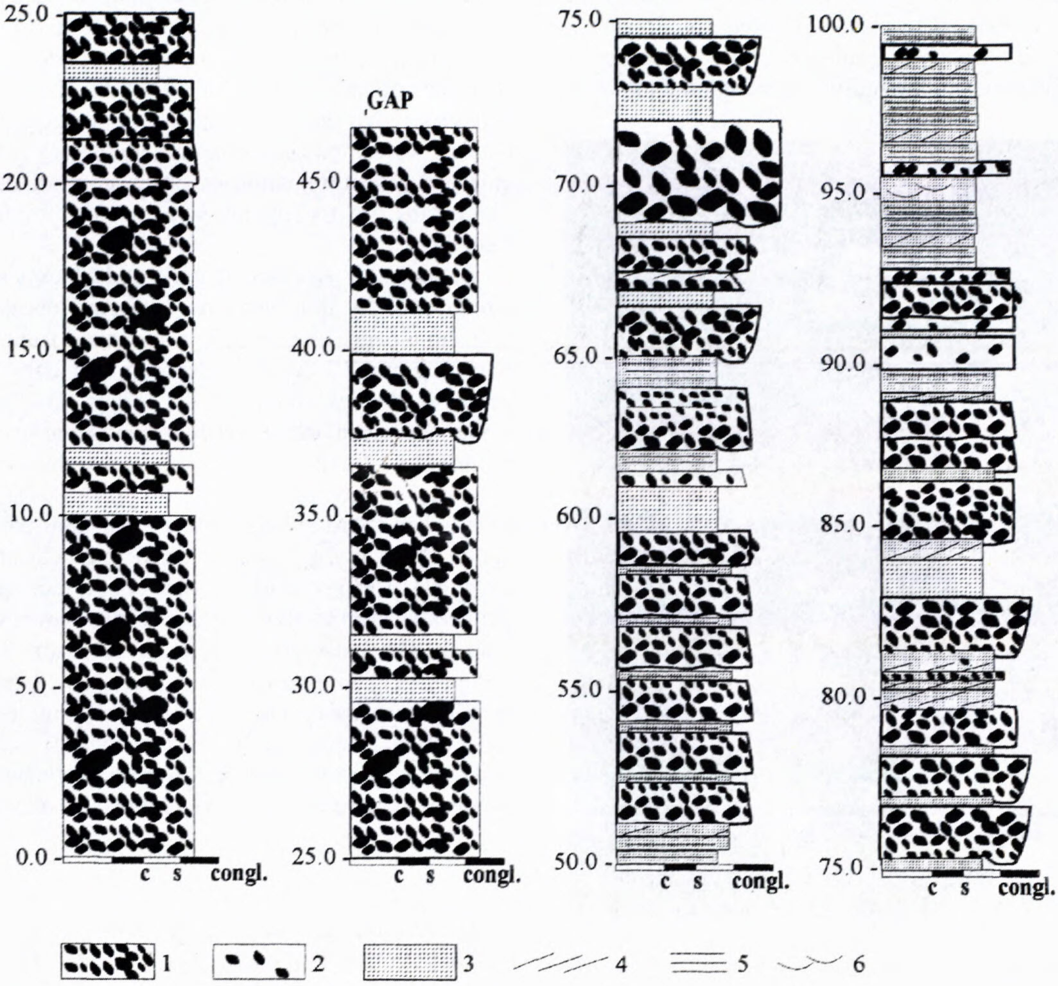

Fig. 4: Sedimentary log showing facies succession of subunit 2-1 overlying subunit 1-1. Note an increase frequency of sandstone beds on the top of the succession. 1 – clast-supported conglomerates, 2 – matrix-supported conglomerates, 3 – sandstone, 4 - cross stratification, 5 - parallel lamination, 6 – trough cross-stratification

contain *Nummulites brongniarti* D'ARCHIAC and *Nummulites puschi* D'ARCHIAC suggesting their Late Bartonian age (planktonic P 14 zone). The clast size of the conglomerates is variable (dolomite clasts up to 100 cm in diameter were observed) and does not show any trend along the profile. The beds are 30 cm to 2 m thick and in the lower part of the unit they are often amalgamated, forming up to 10 m thick bodies separated by thin sandstone beds (Fig. 5). The thickness and frequency of beds decreases upward (Fig. 4). The base of the beds is sharp and erosive. Flute casts developed at the base of some beds in the upper part of the unit show palaeoflow direction toward east. Maršalko & Radomski (1960) found palaeoflow indicators suggesting transport toward N in the lower part of the unit. The conglomerates are prevailingly massive in the lower part and normally and inversely graded in the upper part. The conglomerate beds are separated by pebbly sandstones and medium to coarse-grained sandstones. The sandstones are horizontally laminated and cross-stratified, occasionally normally graded (facies F 4, 5 and F6 of Mutti 1992). Water-escape structures are common (Fig. 6). The pebbles in pebbly sandstones either float in sandy matrix or they form bases of scours. The sharply-based sandstone beds are from a few centimeters to 80 centimeters thick.

Subunit 2-2 consists of black and blackish-brown shales alternating with thick conglomerate and sandstone beds. The shales have macroscopically massive appearance and in thin sections they occasionally show a faint parallel lamination. The Rtg analysis reveal quartz and sericite as main shale minerals. The carbonate content is low with mean value 7%. The mean TOC content is 0.7% (Milička 1998).

The medium-grained, lithic and compositionally immature sandstone, interbedding shales of subunit 2-2, is massive, non-graded and corresponds to F5 facies of Mutti (1992) or facies S3 of Lowe (1982). The sharply based beds are 5 to 30 cm thick. Exception is a conspicuous, 4 m thick sandstone bed set at the top of the subunit. It consists of medium grainedmassive sandstones (Mutti's F5 facies) and contains rip-up mudstone clasts in the lower part of the beds. The individual beds are 30 – 50 cm thick, amalgamated and occasionally separated by shale drapes. The base of beds is sharp and scoured.

The sharply-based conglomerate beds of subunit 2-2 are up to 5 m thick. The clast-supported conglomerates prevail, and the roundness, grain-size and composition of clasts strongly varies in the individual conglomerate beds.

Fig. 5: Alternation of conglomerates and sandstones in the upper part of the canyon fill. The size of the cliff on the photo is about 15 m

The most frequent are subangular clasts of dolomites and limestones having a size from 1 cm to 40 cm. Quartz clasts, up to 5 cm in size, are well rounded and usually represent about 5 – 10% of all clasts. Crystalline clasts and clasts derived from underlying Paleogene deposits (shales, sandstones and conglomerates) are of minor occurrence. The orientation of clasts is random. The conglomerates are mostly massive, normal grading is less frequent.

Subunit 2-3 consists of dark and black shales rarely interlayered by thin sanstone beds and occasional conglomerate beds. The subunit is separated from the underlying subunit 2-2 by a gradational boundary marking a decrease of thick conglomerate bodies. The boundary is tentatively given above the thick sandstone bed set of the subunit 2-2 (Fig. 2). The dark and black shales are similar to shales of subunit 2-2. Macroscopically they are massive and in thin sections they show a faint parallel lamination. The sharply based conglomerate beds are up to 10 cm thick. The prevailingly clast-supported, pebble conglomerates are massive and sometimes they are normally graded. The clast composition is the same like in the subunit 2-2. The sandstone beds are up to 20 cm thick and have a sharp base. They are composed of medium and fine-grained sandstone. The sandstone is massive and rarely it is parallel and ripple-cross laminated showing Bouma's T_{bcd} and T_{cd} divisions (facies F9 of Mutti 1992).

Unit 3

Unit 3 consists of alternating sandstone and shale beds and occasional thin conglomerate beds. The transition from unit 2 is gradual and marked by increasing frequency and thickness of sandstone beds. The alternating

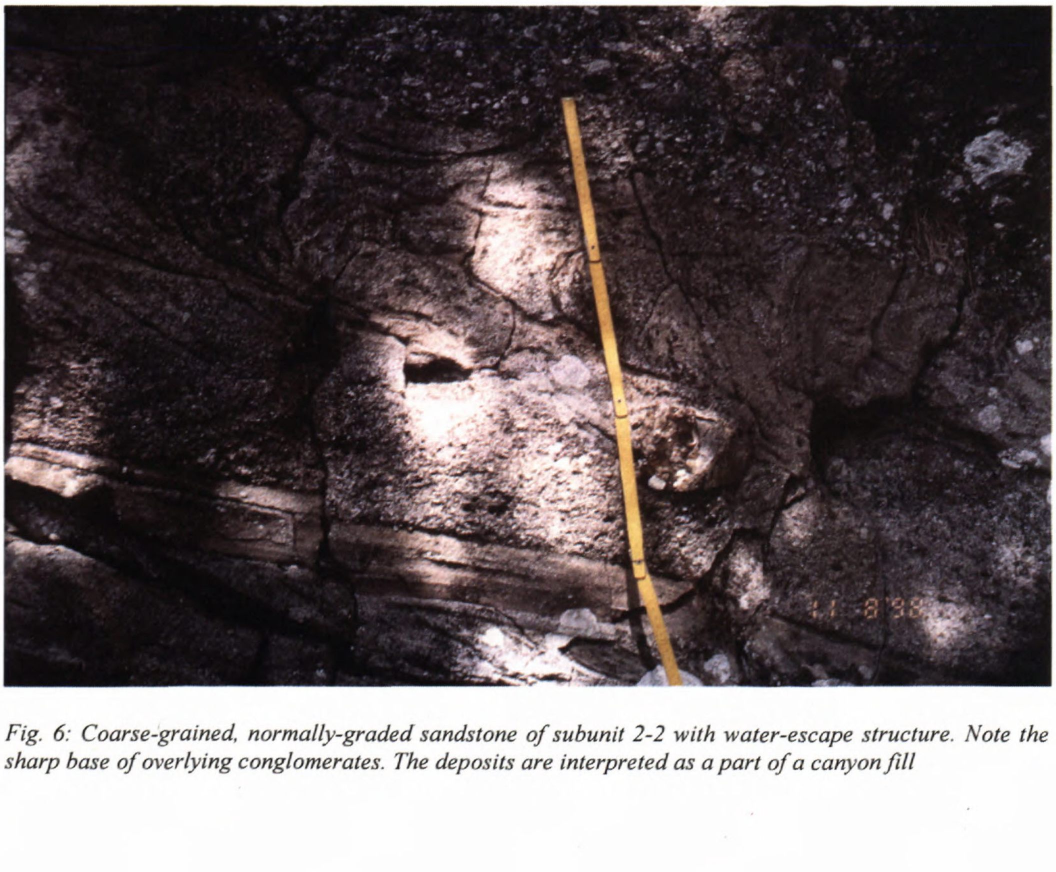

Fig. 6: Coarse-grained, normally-graded sandstone of subunit 2-2 with water-escape structure. Note the sharp base of overlying conglomerates. The deposits are interpreted as a part of a canyon fill

sandstone and shale deposits may be divided into two subunits based on sandstone:shale ratio and sandstone bed thickness. The spatial distribution of both subunits varies both vertically and laterally.

Subunit 3-1 consists of black and dark brown massive and horizontally laminated shales, and occasional ripple-cross laminated silt streaks alternating with sandstone beds with sandstone: shale ratio from 1 : 2 to 1 : 4. The sandstone is fine and medium-grained, massive or horizontally and ripple cross-laminated (facies F5 and F9 of Mutti 1992). The thickness of beds usually does not exceed 15 cm. Laterally they pinch out very slowly, in a 2.5 km long section a 30 cm thick bed thinned to 5 cm thick bed (Fig. 7). The base of beds is sharp and scoured and frequently loaded, flute casts and groove marks indicate a palaeoflow direction toward SE and E. The conglomerate beds are sharply-based and up to 15 cm thick. The exception is a 30 m thick slump body composed of conglomerates with chaotic structure. The conglomerates consist of Mesozoic carbonates, quartz, granitoids, metamorphic rocks, Mesozoic and Paleogene sandstones and shales.

Subunit 3-2 consists of alternating sandstone and shale beds with ratio 1:1, 1:2 (Fig. 8). The shales have the same characteristics as shales in subunit 3-1, the massive and normally graded sandstones are medium to coarse-grained, faintly horizontally and ripple cross-laminated. The thickness of sandstone beds varies from 5 cm to 70 cm, sometimes they laterally pinch out. The base of beds is sharp, scoured with flute casts and groove marks suggesting palaeotransport direction toward east and south-east. Occasionally, starving ripples and synsedimentary slump folds occur (Fig. 8). In the sandstone nummulites of the Priabonian age were found.

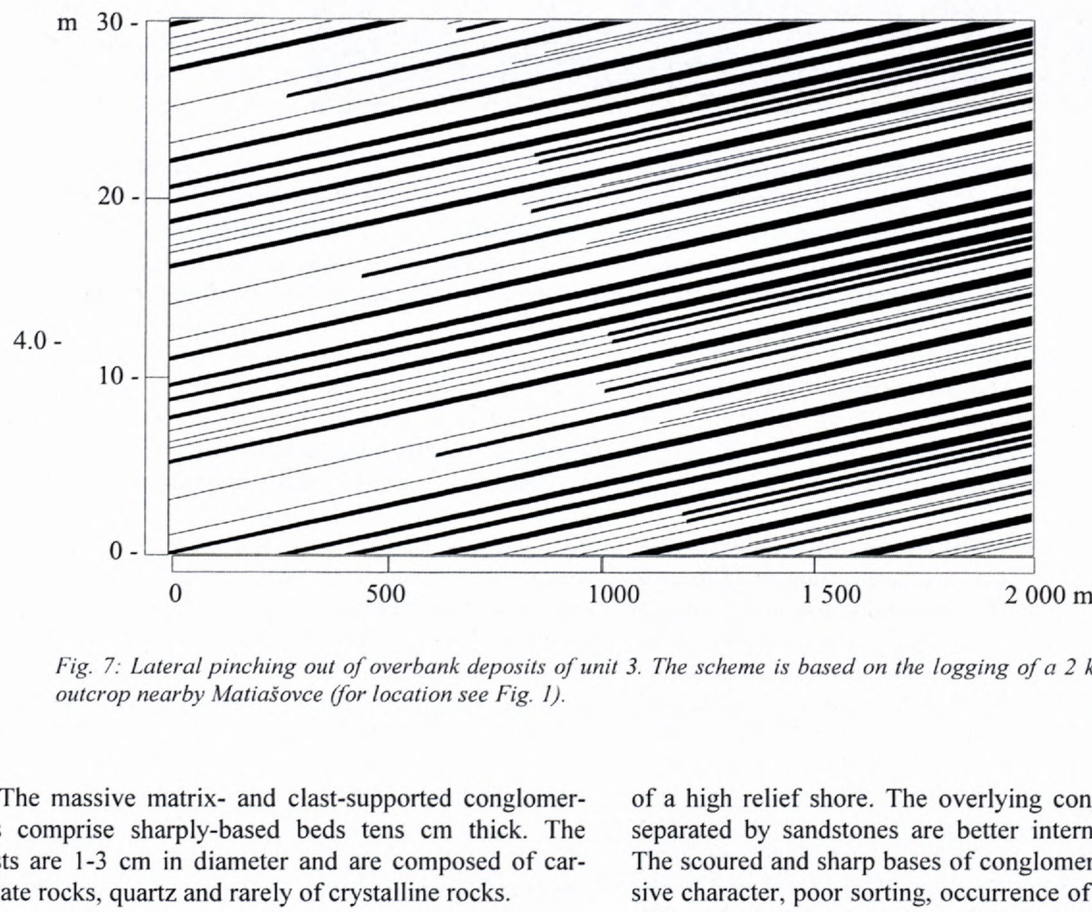

Fig. 7: Lateral pinching out of overbank deposits of unit 3. The scheme is based on the logging of a 2 km long outcrop nearby Matiašovce (for location see Fig. 1).

The massive matrix- and clast-supported conglomerates comprise sharply-based beds tens cm thick. The clasts are 1-3 cm in diameter and are composed of carbonate rocks, quartz and rarely of crystalline rocks.

Interpretation

Unit 1

The features of the breccias of subunit 1-1, sharp-edged clasts of coarse gravel to block size, poor sorting, weak internal organization as well as composition of clasts derived from the directly underlying Mesozoic basement, suggest extremely short transport during deposition. The lack of internal organization of the breccias and the occurrence of large carbonate clasts suggest prevailing rock fall depositional mechanism in front of cliffs of a high relief shore. The overlying conglomerate beds separated by sandstones are better internally organized. The scoured and sharp bases of conglomerates, their massive character, poor sorting, occurrence of separating parallel and cross-laminated sandstones and fining-upward trend in 6-8 m thick cycles hint at deposition by fluctuating traction flow. The admixture of rounded quartz clasts in the conglomerates, which do not occur in the surroundings of the studied area, suggests a distant source area. We think that these sediments were deposited on a high gradient slope in a delta fan environment by hyperpycnal flow (e.g. Bornhold & Prior 1990). The quartz clasts were transported by a fluvial system and distributed in a fan delta. The fluctuation of the flow was probably cuased by allocyclic mechanism (tectonics?, climate?).

Poor outcrops of the nummulitic sandstone and sandy limestone forming subunit 1-2 does not allow to make

Fig. 8 Levee deposits of subunit 3-2. Note a sedimentary fold in the middle of the photo.

more precise conclusions concerning depositional environment. The gradual transition from the underlying conglomerates of subunit 1-1 and the occurrence of well-preserved fragile tests of nummulites (E. Köhler, personal comm. 1999) throughout the sandstone and limestone point to their position *in situ.* The lack of any tractional structures is thought to be a result of sediment homogenization by burrowing. The presence of nummulites suggests an environment with water depth up to 100 m.

Unit 2

Conglomerate and sandstone deposits of subunit 2-1 are interpreted as a fill of submarine canyon. The estimated 60 meters of incision into underlying unit 1 suggest a striking relative sea level fall. The clast composition of conglomerates suggest several source areas. The dolomite and limestone clasts were probably derived from the local coast formed by Mesozoic rocks. The crystalline rocks did not occur in the vicinity of the studied area suggesting a distant source for the crystalline and quartz clasts. Their occurrence implies a continual activity of the fan delta yielding quartz clasts to subunit 1-1 although the type of deltaic system and the lithology of its source area might be changed. The presence of Paleogene clasts indicates erosion (cannibalism) of older basin fill deposits probably related to relative sea level fall. *Nummulites brongniarti* D'ARCHIAC and *Nummulites puschi* D'ARCHIAC found in the clasts are not of local origin; the closest area of their occurrence is nearby Zakopane (E. Köhler, personal comm. 1999, Fig. 1) implying efficient tranport by longshore currents.

The prevailingly massive conglomerates in the lower part of the succession are interpreted as deposits of cohesive debris flows (e.g. Nemec & Steel 1984, Mutti 1992, Nelson & Nilsen 1997). The frequent amalgamation and only minor occurrence of sandstone beds suggest erosional ability of flows. Better internal organization of conglomerate beds upward (normal and inverse grading) is thought to be a result of deposition from hyperconcentrated flows. The flows originated by dilution of cohesive debris flows by ambient water. The erosional ability of these flows was already low as shown by sharp bed bases and increased occurrence of separating sandstone beds. The traction and water-escape structures of sandstones indicate further flow transformation to high-density turbidites (e.g. Nemec & Steel 1984, Mutti 1992).

The black and blackish-brown shales with thick conglomerate and sandstone beds comprising subunit 2-2 are interpreted as basin slope and base-of-slope deposits. The shales were deposited from suspension clouds in a submarine slope (or steeply inclined ramp, Fig. 9) environment. The mean TOC content 0.7% suggests weak circulation and intensive input of organic matter.

The poor sorting, weak internal organization and sharp bases of thick conglomerate beds are indicative for deposits of cohesive debris flows (e.g. Hampton 1975, Reading & Richards 1994). Rare normal graded beds suggest dilution of the upper part of debris flows and generation of hyperconcentrated flows (e.g. Lowe 1975, Nemec & Steel 1984, Mutti 1992). The conglomerates probably originated by slope failures on shelf edge connected to relative sea level fall. The excess of sediments on the shelf edge may be partly connected to building of deltaic system feeding canyon fill of subunit 2-1.

The medium-grained massive sandstones (facies F5 of Mutti 1992, S3 of Lowe 1982) of subunit 2-2 are interpreted as high-density turbidity current deposits. The generation of these turbidity currents is also ascribed to slope failures on shelf edge during relative sea level fall. The compositional immaturity of sandstones implies that the sediments were derived from rapidly uplifted highlands and were not subjected to prolonged abrasion in a transitional, high-energy depositional setting such as beach, shoreface etc. It suggests a narrow, faulted shelf (e.g. Bruhn & Walker 1995).

The deposits of subunit 2-3, consisting of dark and black shales, thin sandstone beds and rare conglomerates, are thought to be deep-water deposits originated during relative sea level rise. The massive and faintly parallel-laminated shales were deposited from suspension clouds.

The occasional medium and fine-grained sandstones showing Bouma's T_{bcd} and T_{cd} divisions (facies F9 of Mutti 1992) were deposited by low-density turbidity flows. The rare massive conglomerates were probably deposited by debris flows generated by storms on shelf. The low frequency of sandstone and conglomerate beds implies decreasing activity of deltaic building.

Unit 3

The sandstone beds alternating with shales are interpreted as overbank deposits of a turbidite system. The inferred palaoeflow toward SE and E implies basin axial position of this system. Subunit 3-1, consisting of thin, laterally pinching out sandstone beds alternating with shales probably represents distal overbank deposits deposited by turbidite flows spilled over channel levee (e.g. Imperato & Nilsen 1990, Janočko et al. 1998). The very slow lateral thinning of beds suggests positive morphostructure of this part of a turbidite system. The higher frequency and increased thickness of sandstone beds of subunit 3-2, as well as abrupt pinching out, synsedimentary folds and starving ripples indicate deposition on levee slope closer to the channel.

The massive, sharply based conglomerates with massive and chaotic structures are interpreted as slump and debris flow deposits generating by slope failures. The occurrence of crystalline rocks in the clast composition suggest a constructive phase of deltaic building. The deposits of unit 3 are thought to be originated during relative sea level fall.

Implication for basin history

The composed sedimentary succession in the region of Spišská Magura consists of basal breccias and conglomerates overlain by nummulitic sandstones and limestones (unit 1) which are, in turn, overlain by coarse-grained canyon fill deposits (subunit 2-1), shales with thick conglomerate and sandstone beds (subunit 2-2) and shales containing thin sandstone beds (subunit 2-3). The whole succession is capped by alternating shale and sandstone beds (unit 3, Fig. 2). Based on biostratigraphy, the age of the succession is ranging from the Late Bartonian to the Early Rupelian.

The lowermost deposits of unit 1 were deposited during marine transgression and represent transgressive systems tract (Fig. 9). The first marine incursion to the studied region is assumed to be from the W, NW and N (Gross et al. 1980, 1993). The conglomerates prevailingly consisting of carbonate clasts suggest rugged coastal relief gradually destructed by marine erosion. A minor amount of the conglomerate clasts is composed of quartz from distant source area. The occurrence of quartz and the conglomerates separated by sandstones imply depositional system of a fan delta on a high-gradient shelf. However, the more intensive deltaic deposition was probably suppressed by rising sea level.

The coarse-grained deposits of subunit 2-1 and shales with conglomerates and sandstones of subunit 2-2 are thought to be deposited during relative sea level fall representing a lowstand systems tract (Fig. 9). The clast composition of the conglomerates suggests several sources and input of sediments by both deltas and longshore currents. The occurrence of clasts composed of older Paleogene rocks (Bartonian, P 14 zone indicated by *Nummulites brongniarti* D'ARCHIAC and *Nummulites puschi* D'ARCHIAC which are not common in basal deposits of the studied region) implies an important role of tectonics in the basin evolution which probably was the main factor triggering the change of relative sea level in the basin at that time. The basal deposits of unit 1 representing transgressive systems tract should be located on the basin margin and all the older Paleogene deposits should be located more basinward, thus stratigraphically below them. If the sea level fall during the deposition of subunits 2-1 and 2-2 was induced by eustatic sea level fall we should first expect erosion of the unit 1 deposits and only after then erosion of older Paleogene deposits. The clasts composed of Bartonian rocks in the canyon fill and conglomerate bodies of subunit 2-2 suggest tectonic uplift of some basinal parts composed of older Paleogene deposits which became source areas for canyon fill deposits and subunit 2-2 conglomerates. According to Maršalko and Radomski (1960) the palaeoflow was toward N indicating lateral sediment input into the basin.

The shales of subunit 2-3 reflect deposition in a quiet, low-energy environment during rise of sea level. The occasional thin beds of sandstones represent low-density turbidites probably generated by storms on shelf.

The gradual transition to the unit 3, interpreted as turbidite system deposits, suggests lowering of relative sea level. The nanoplankton from these deposits was mostly assigned to the nanoplankton zones NP 20-21 suggesting building of this turbidite system on the boundary between Eocene and Oligocene. The palaeoflow direction was parallel to the basin axis and oriented toward SE and E.

The main processes involved in formation of sedimentary succession are sea level variations , tectonics, sediment supply and climate (Rasmussen 1997). Comparison of the sea level curve inferred from our research to the eustatic sea level for Middle and Late Eocene and Early Oligocene (according to Abreau & Anderson 1998) shows little match (Fig. 9) suggesting that the eustatic sea level variation was not the main trigger responsible for the sedimentation in the investigated part of the CCP Basin. Similarly the climate during the Late Eocene and Early Oligocene was stable (Brinkhuis 1994) and probably did not influenced the sedimentation. It seems that the most important factor influencing sedimentation was the tectonic activity. It controlled basin size and shape, canyon floor gradient, shelf width and local relative sea level (e.g. Stow et al. 1985, Mutti & Normark 1987) determining the type of sedimentation and resulting sedimentary succession.

Conclusion

The sedimentary fill of the northern Slovak part of the CCP Basin (Spišská Magura region) consists of three

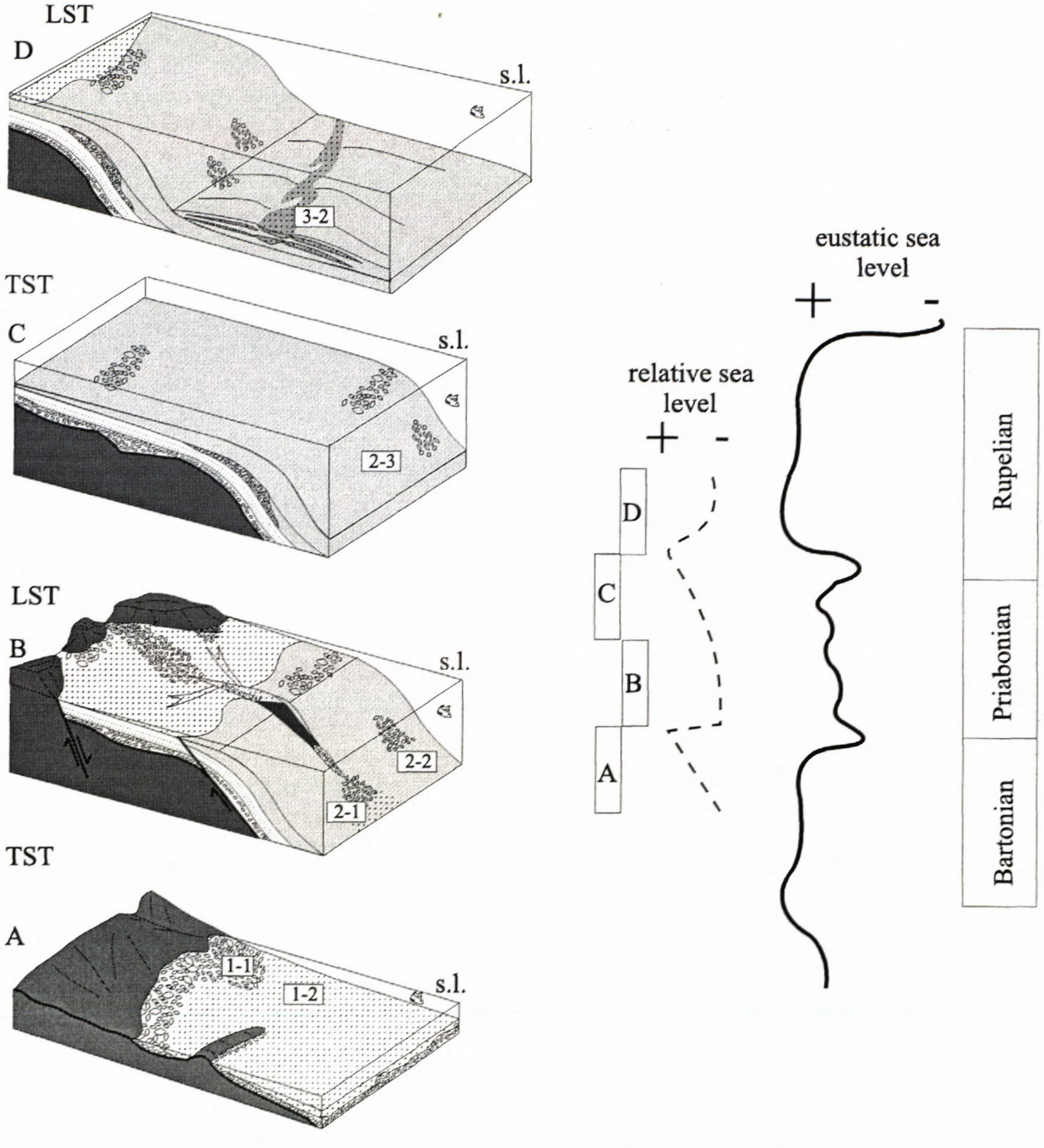

Fig. 9: Blockdiagrams showing development of the studied deposits in a time succession and comparision to the inferred and eustatic sea level curve. The eustatic sea level curve after Abreu and Anderson 1998. LST - lowstand systems tract, TST - transgressive systems tract. The arrows in the blockdiagrams B and D show the main palaeocurrent directions.

main lithologic units (Fig. 2) reflecting the basin sedimentary and tectonic history:

- Unit 1 consisting of basal breccias, conglomerates and nummulitic sandstones and sandy limestones;
- Unit 2 consisting of coarse-grained canyon fill, shales with thick conglomerate and sandstone beds and shales with thin sandstone and occasional conglomerate beds;
- Unit 3 consisting of alternating shale and sandstone beds

The age of unit 1 ranges from the Late Bartonian to the Priabonian based on nummulites analyses (planktonic foraminifera zones P14-P15). The age of units 2 and 3 is constrained by nanoplankton zones NP 17 –21 (Bartonian – Rupelian). The redeposited large foraminifera in the unit 2 deposits indicate early and middle Priabonian age (P 15 – P 16 zones). The occurrence of redeposited large foraminifera in the unit 3 deposits suggest early to late Priabonian age (P15 – P 17 zones).

Unit 1 was deposited during marine transgression in the Late Bartonian and Priabonian and represents transgressive systems tract. The sedimentation occurred on relatively steeply inclined shelf.

Unit 2 is composed of three subunits. The coarse-grained deposits of subunit 2-1 and shales with thick conglomerate and sandstone beds represent the lowstand systems tract. The relative sea level fall during this phase is mainly assigned to the local tectonic activity. The subunit 2-3 consisting of shales with thin sandstone and conglomerate beds represents the transgressive systems tract.

Unit 3 is composed of alternating sandstone and shale beds and represents the lowstand systems tract. The deposits are part of the basin axial turbidite system.

The timing and environmental interpretation of the studied deposits provides some new knowledge on the CCP Basin history. The most important determinant governing the sedimentation seems to be tectonics. We also suggest that the shales of subunit 2-2 does not necessarily represent a deep water deposition during one sedimentation cycle as assumed so far (e.g. Baráth et al. 1997, Buček et al. 1998). We did not find any striking evidence of an abrupt basin subsidence (often termed as a collapse) neither in the studied area of the CCP Basin nor in the neighbouring area of the Tatras where a continual succession of Mesozoic rocks can be found. Contrarily, we think that the subunit 2-2 shales may represent deposition during lowstand of relative sea level. However, our interpretation is still preliminary and we need further regional data to support our study.

Acknowledgement

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Freshwater gastropods of Upper Pannonian age in the northern part of the Danube basin

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Abstract: Upper Pannonian sediments of the Danube basin, that form parts of the Beladice Formation and Hlavina Member, developed in a freshwater environment . The marginal facies of these sediments contain terrestrial and freshwater gastropod fauna. In this article, the results of terrestrial gastropods study is summarized and an information is also given on the freshwater gastropods that were systematically investigated at the localities Orešany-(borehole PID-1), Orešany-road cut, Čeľadince, Koplotovce and Jelenec. Alltogether 12 species of gastropods belonging to 10 genera were described.

Key words: Western Carpathians - Danube basin - Pannonian - Freshwater gastropods - System

Introduction

Upper Pannonian sediments (in the sense of the Rögl et al., 1993) developed in a freshwater environment in the Danube Basin. They form parts of the Beladice Formation (F zone of the Pannonian) (Harčár - Priechodská et al., 1988) and of Hlavina Member (H zone of the Pannonian) (Fordinál - Nagy, 1997).

No fauna of stratigraphic significance was found in the past in the mentioned sediments. But during the last few years we found stratigraphically significant taxa of mollusc in the marginal facies of these sediments (Fordinál, 1994; 1996; Fordinál - Nagy, 1996; Fordinál et al., 1996).

The recovered association of mollusc is predominated by gastropods, while the bivalves, represented by the genus *Pisidium*, are of scarce occurrence. The association of gastropods contains both, terrestrial and freshwater forms. While the former were systematically studied and described (Fordinál, 1996; Fordinál - Nagy, 1996) this paper brings an information on the freshwater gastropods, especially on the species of stratigraphic significance (tab. 1).

Tab. 1 Stratigraphic range of selected gastropods species (Sauerzopf, 1953; Stojaspal, 1990)

Druhy	M I O C É N							
	P a n ó n							
	A	B	C	D	E	F	G	H
Valvata oecsensis						—	—	—
Planorbis confusus								—
Anisus krambergeri								—
Bathyomphalus moedlingensis								—
Armiger subtychophorus								—
Segmentina loczyi								—
Segmentina filicincta								—

Characterization of studied localities

Freshwater gastropods from the localities: Orešany - borehole PID-1, Orešany - road cut, Čeľadince, Koplotovce and Jelenec (Fig. 1) were studied.

Orešany - borehole PID-1

The hydrogeological borehole PID-1, situated about 500 m SW of the Orešany village, was drilled in order to obtain a source of water for this village. The core is represented by the lacustrine chalk, freshwater limestones and green clays that grade upwards into rusty-spotted clays. These rocks contain a rich fauna represented by gastropods, bivalves, ostracodes, otoliths, claws of freshwater crabs and gyronites of characeans (Fordinál, 1994). On the basis of the obtained fauna, these sediments were biostratigraphically assigned to the H zone of the Pannonian. Previously, this sequence, was classified as a stratotype for the marginal Upper Pannonian sediments - the Hlavina Member (Fordinál - Nagy, 1997).

While the terrestrial gastropods from this borehole were already described (Fordinál, 1996), in the presented paper the freshwater gastropods are dealt with.

Orešany - road cut

In the road cut in the Orešany village there crop out green calcareous clays that grade upward into light-grey clays and further upward into light-grey rusty-spotted to brown clays. Conches of freshwater, terrestrial gastropods and tests of ostracodes were identified in them. Of the freshwater gastropods there occur *Valvata helicoides* STOLICZKA, *Anisus* sp., *Segmentina filocincta* (SANDBERGER), *Bithynia* sp. *(operculum), Lymnaea* sp.,

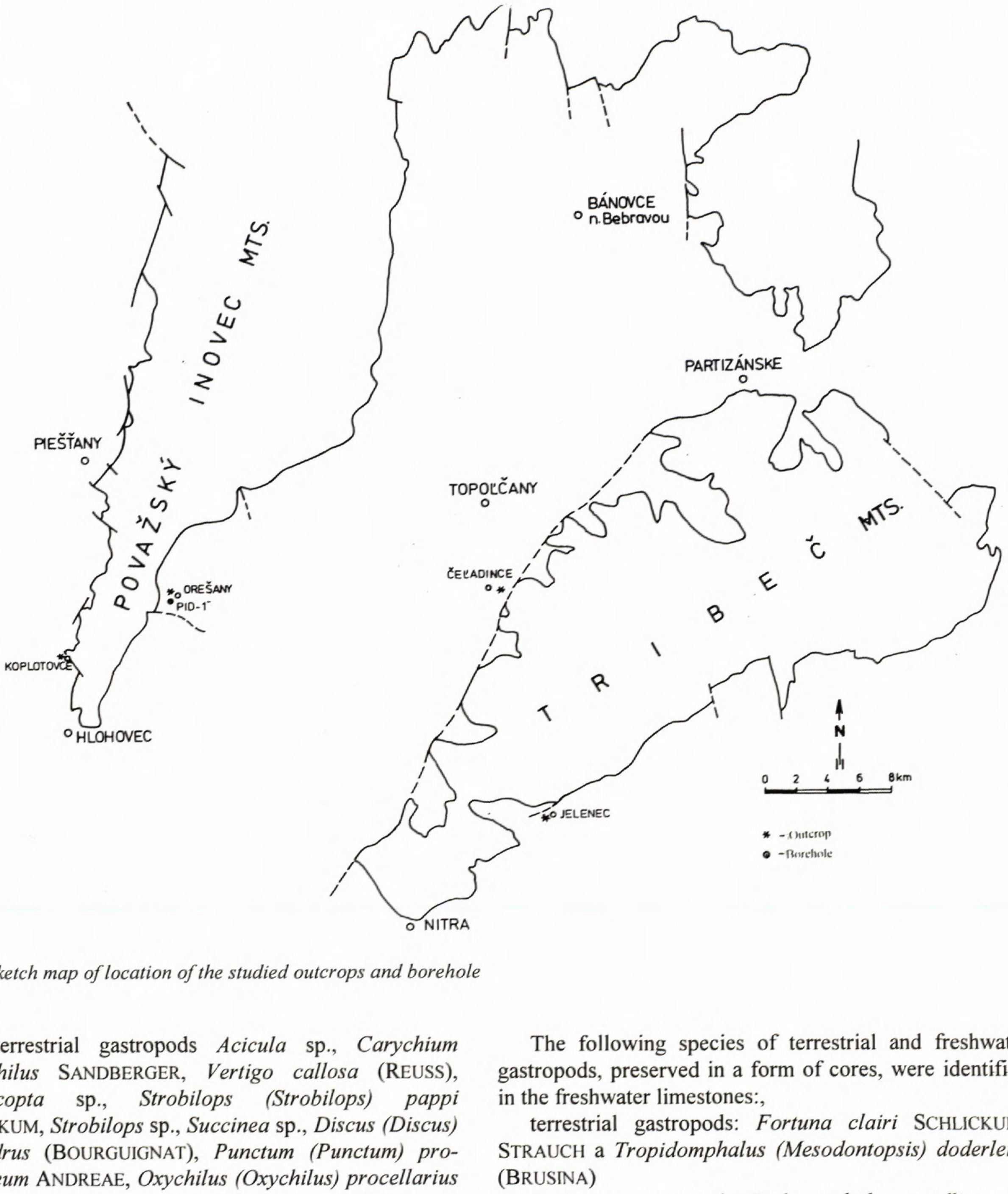

Fig. 1 Sketch map of location of the studied outcrops and borehole

from terrestrial gastropods *Acicula* sp., *Carychium pachychilus* SANDBERGER, *Vertigo callosa* (REUSS), *Gastrocopta* sp., *Strobilops (Strobilops) pappi* SCHLICKUM, *Strobilops* sp., *Succinea* sp., *Discus (Discus) pleuradrus* (BOURGUIGNAT), *Punctum (Punctum) propygmaeum* ANDREAE, *Oxychilus (Oxychilus) procellarius* (JOOS) and of the ostracodes *Candona (Typhlocypris) roaixensis* CARBONELL (FORDINÁL, 1988).

Čeľadince

Near Čeľadince, in the field-path cut situated SE of mentioned village, there crop out the Upper Pannonian freshwater sediments (freshwater limestones, travertines and clays). It is a denudation remmant at the boundary between the Mesozoic limestones and Neogene fill of the Rišňovce depression.

This occurrence is a parastratotype locality of the Hlavina Member (Fordinál - Nagy, 1997).

The following species of terrestrial and freshwater gastropods, preserved in a form of cores, were identified in the freshwater limestones:,

terrestrial gastropods: *Fortuna clairi* SCHLICKUM-STRAUCH a *Tropidomphalus (Mesodontopsis) doderleini* (BRUSINA)

freshwater gastropods: *Bathyomphalus moedlingensis* Sauerzopf , *Planorbis confusus* Soós.

From the greenish-grey clays, root concretions, operculum of gastropods of the genus *Bithynia* and ostracodes *Candona (Typhlocypris) roaixensis* CARBONELL, *C. (Pontoniella) loczyi* (ZALÁNYI) and *Candona* sp. (FORDINÁL et al., 1996) were encountered.

Koplotovce

In the field below the road connecting Koplotovce and Jalšové villages, (about 700 m N of Koplotovce), there occur greenish-grey clays in which the gastropods *Val-*

Plate I

Fig. 1 *Viviparus* cf. *semseyi* HALAVÁTS, Orešany , borehole PID-1 (22,0-22,1 m)
2 *Valvata* (*Valvata*) *oecsensis* SOÓS, Koplotovce
3 *Valvata (Valvata) helicoides* STOLICZKA, Orešany-road cut
4 *Planorbis confusus* (SOÓS), Orešany, borehole PID-1 (22,0-22,1 m)
5 *Anisus krambergeri* (HALAVÁTS), Orešany, borehole PID-1 (36,5-36,6 m)

vata oecsensis (Soos), Brotia sp., ?*Lymnaea* sp. a *Limax* sp. were found. Besides gastropods fragments of crab claws of the genus *Potamon* were also found (FORDINÁL, 1998).

The occurrence of fauna in the Neogene sediments near Koplotovce was first reported at the beginnining of this century. The gastropods *Melanopsis Entzi* BRUS., *Pyrgula (Micromelania) costulata* FUCHS., *Planorbis* cf. *bakonicus* HALAV., *Valvata helicoides* Stol., *Valvata* sp., *Neritina (Neritodonta) radmanesti* FUCHS., *Melania* nov. sp. and the bivalves *Unio* sp. and *Pisidium* sp" were described by HORUSITZKY (1911).

Later on, ČTYROKÝ (1959) studied the molluscan fauna in the surroundings of Koplotovce. He reported that in the road cut north of this village, but also in the exposures of greenish-grey, or brownish-rusty, in places bluish, slightly fine, sandy calcareous clays below the road thee occur the following species: *Theodoxus* cf. *moosbrunensis* PAPP, *Brotia escheri* nov. ssp., *Melanopsis fuchsi* HANDMANN, *Valvata öcsensis* (SOÓS), *Gyraulus* sp., *Unio* sp., and *Pisidium* sp.(?).

CICHA (1955) also found the ostracode fauna in the clays near Koplotovce. He identified the species *Candona* cf. *bodonensis* POKORNÝ, *Erpetocypris abscisa* (RSS.) and a test fragment of the genus *Cyprideis*..

Jelenec

Near the Jelenec village there crop outgrey clays with intercalations of coaly clays in a railway cut,.

These clays contain abundant carbonised plant chaff. They attain a thickness of 2 m. Amidst them, a 10 to 40 thick, irregular layer of greyish-black to black coaly clay is located. These clays contain shells of gastropods *Valvata helicoides* STOLICZKA, *Gyraulus* cf. *subptychophorus* HALAVÁTS, *Carychium* sp., a calcified egg of gastropod and tests of ostracodes *Ilyocypris* sp., *Candona* (*Bakunella*) sp., *Candona (Pseudocandona) marchica* (HARTWIG), *Candona (Fabaeformiscandona)* cf. *lineata* KRSTIC, *Candona (Typhlocypris) roaixensis* (CARBONELL), *Darvinulla* sp.. Besides ostracodes, redeposited spherical radiolarians were also found in clays (FORDINÁL in IVANIČKA et al., 1998).

Systematic part

Class	*Gastropoda*
Subslass	*Prosobranchia*
Order	*Mesogastropoda*
Family	*Viviparidae*
Genus	*Viviparus* MONTFORT, 1810
Type species	*Helix vivipara* LINNÉ, 1758

***Viviparus* cf. *semsey* HALAVÁTS, 1902**
(Pl. 1, Fig. 1)

1911 *Viviparus Semseyi* HALAVÁTS. - HALAVÁTS: p. 43, Pl. 1, Fig. 11-12

Material: 1 specimens from Orešany, borehole PID-1
Description: Halaváts (1911) p. 43
Dimension: Pl. I, Fig. 1 height=18 mm width=16,6 mm
Occurrence in the Western Capathians: Orešany, borehole PID-1 (22,0-22,1 m)
Stratigraphic range and geographic extension: The mentioned species has been known from Upper Pannonian sediments of Hungary (Nagy-Berény) so far only.

Family	*Valvatidae*
Genus	*Valvata* MÜLLER, 1774
Subgenus	*Valvata* s. str.
Type species	*Valvata piscinalis* MÜLLER, 1774

***Valvata (Valvata) oecsensis* SOÓS, 1934**
(Pl. I, Fig. 2)

1911 *Valvata helicoides* STOLITZKA. - HALAVÁTS: p. 38, Pl. 3, Fig. 1
1934 *Valvata (Valvata) simplex öcsensis* n. f. - SOÓS: p. 189, Fig. 1
1942 *Valvata (Valvata) öcsensis* SOÓS. - WENZ-EDLAUER: p. 83, Pl. 4, Figs. 1-2
1953 *Valvata öcsensis* SOÓS - PAPP: p. 109, Pl.. 4, Figs. 12-13
1978 *Valvata oecsensis* SOÓS - SCHLICKUM: p. 246, Pl.. 18, Fig. 1

Material: 2 specimens from Koplotovce
Description: Soós (1934) p. 189
Occurrence in the Western Capathians: Koplotovce
Stratigraphic range and geographic extension: The occurrence of this species was established in the F-H Zone of the Pannonian in Austria (Eichkogel, Trautmannsdorf, Rechnitz), in G-H zone of the Pannonian in Slovakia (Koplotovce) and in the Upper Pannonian of Hungary (Öcs, Kenese).

***Valvata (Valvata) helicoides* STOLICZKA, 1862**
(Pl. I, Fig. 3)

1979 *Valvata (Valvata) helicoides* STOLICZKA - SCHLICKUM: p. 407, Pl. 23, Fig. 1

Material: 2620 specimens from Orešany, borehole PID-1 and 220 specimens from Orešany, road cut
Description: Schlickum (1979) p. 407
Occurrence in the Western Carpathians: Orešany, borehole PID-1 (4,0-4,2 m; 9,8-10,0 m; 10,0-10,4 m; 13,0-13,1 m; 22,0-22,1 m; 28,7-28,8 m; 32,0-32,3 m; 36,0-36,1 m; 36,5-36,6 m), Orešany - road cut, Jelenec
Stratigraphic range and geographic extension: This species is found in the Upper Pannonian of Hungary (Öcs), in F-H Zone of the Pannonian in Slovakia (Jelenec, Orešany).

Subclass	*Pulmonata*
Order	*Archaeopulmonata*
Family	*Physidae*
Genus	*Aplexa* FLEMING, 1820
Type species	*Bulla hypnorum* LINNÉ, 1758

***Aplexa subhypnorum* GOTTSCHICK**

1959 *Aplexa subhypnorum* GOTTSCHICK - BODA: p. 638, Pl. 37, Fig. 5-6
1978 *Aplexa subhypnorum* GOTTSCHICK - GOŽIK - PRISJAŽNJUK: p. 71, Pl. 3, Fig. 2

Material: 60 specimens from Orešany, borehole PID-1, 1 specimen (cf.) from Malé Kršteňany-quarry
Description: Boda: p. 638
Occurrence in the Western Carpathians: Orešany, borehole PID-1 (9,8-10,0 m; 22,0-22,1 m; 28,7-28,8 m; 32,0-32,3 m; 36,0-36,1 m; 36,5-36,6 m), Malé Kršteňany-quarry
Stratigraphic range and geographic extension: This species is known from Sarmatian and Pannonian of Hungary, Ukraine and Upper Pannonian of Slovakia.

Family *Planorbidae*
Genus *Planorbis* MÜLLER, GEFFROY, 1767
Type species *Helix planorbis* LINNÉ, 1758

***Planorbis confusus* (SOÓS, 1934)**
(Pl. I, Fig. 4)

1934 *Anisus (Anisus) confusus* n.sp. - SOÓS: p. 194, Fig. 5
1942 *Anisus (Anisus) confusus* Soós - WENZ-EDLAUER: p. 86
1953 *Planorbis (Anisus) confusus* SOOS - SAUERZOPF: p. 53, Pl. 2, Fig. 1a-c
1954 *Planorbis confusus* SOÓS - BARTHA: p. 178
1955 *Planorbis (Anisus) confusus* SOÓS - BARTHA- SOÓS: p. 64, Pl. 5, Fig. 1-4

Material: 38 specimens from Orešany, borehole PID-1, 1 specimen from Čeľadince
Description: SOÓS (1934) p. 194
Occurrence in the Western Carpathians: Orešany, borehole PID-1 (32,0-32,3 m; 36,0-36,1 m), Čeľadince
Stratigraphic range and geographic extension: The occurrence of this species is known from the H Zone of the Pannonian in Austria (Eichkogel, Königsberg), Slovakia (Orešany, Čeľadince) and from the Upper Pannonian of Hungary (Öcs, Balatonszentgyörgy).

Genus *Planorbarius*
Type species *Helix corneus* LINNÉ, 1758

***Planorbarius thiollieri* (MICHAUD, 1855)**
(Pl. II, Fig. 5)

1942 *Planorbarius thiollieri* (MICHAUD). - WENZ-EDLAUER: p. 86
1953 *Planorbarius thiollieri* (MICHAUD) - SAUERZOPF: p. 50, Pl. 1, Fig. 5

Material: 1 specimen from Orešany, borehole PID-1,
Description: Sauerzopf (1953) p. 50
Occurrence in the Western Carpathians: Orešany, borehole PID-1 (36,0-36,1 m)
Stratigraphic range and geographic extension: The occurrence of this species is known from the Miocene to Pliocene of Europe.

Genus *Anisus* STUDER, 1820
Type species *Helix spirorbis* LINNÉ, 1758

***Anisus krambergeri* (HALAVÁTS, 1911)**
(Pl. I, Fig. 5)

1911 *Planorbis Krambergeri* n.sp. - HALAVÁTS: p. 56, Pl. 3, Fig. 3
1911 *Odontogyrorbis Krambergeri* HALAVÁTS. sp. - LÖRENTHEY: p. 121, Pl. 2, Fig. 17
1934 *Anisus (Odontogyrorbis) Krambergeri* HALAV. - SOÓS: p. 193
1942 *Anisus (Odontogyrorbis) krambergeri* (HALAVÁTS) - WENZ-EDLAUER: p. 86, Pl. 4, Fig. 6
1953 *Planorbis (Odontogyrorbis) krambergeri krambergeri* HALAVATS - SAUERZOPF: p. 53, Pl. 3, Fig. 1a-d
1954 *Planorbis krambergeri* (HALAV.) - BARTHA: p. 177, Pl. 1, Fig. 5
1959 *Planorbis krambergeri* (HALAVÁTS, 1903) - BARTHA: p. 77, Pl. 14, Figs. 7, 10, 12
1978 *Anisus (Anisus) krambergeri* (HALAVÁTS). - SCHLICKUM: p. 250, Pl. 18, Fig. 8
1978 *Anisus (Odontogyrorbis) krambergery* HALAVATS - GOŽIK-PRISJAŽNJUK: p. 76, Pl. 31, Fig. 3-5

Material: 400 specimens from Orešany, borehole PID-1,
Description: HALAVÁTS (1911) p. 56
Occurrence in the Western Carpathians: Orešany, borehole PID-1 (4,0-4,2 m; 9,8-10,0 m; 10,0-10,4 m; 13,0-13,1 m; 22,0-22,1 m; 28,7-28,8 m; 32,0-32,3 m; 36,0-36,1 m; 36,5-36,6 m)
Stratigraphic range and geographic extension: This species is found in the Upper Sarmatian of Ukraine (Nikolajev), Upper Pannonian of Hungary (Öcs, Fonyód, Kenese, Tihany, Nagyvászony, Kozma) and in the H Zone of the Pannonian in Austria (Eichkogel) and Slovakia (Orešany).

Genus *Bathyomphalus* AGASSIZ, 1837
Type species *Helix contortus* LINNÉ, 1758

***Bathyomphalus moedlingensis* SAUERZOPF, 1953**

1953 *Planorbis (Bathyomphalus) mödlingensis* n. sp. - SAUERZOPF: p. 66, Pl. 4, Fig. 4a-c

Material: 3 specimens from Čeľadince
Description: Sauerzopf (1953) p. 66
Occurrence in the Western Carpathians: Čeľadince
Stratigraphic range and geographic extension: This species is known from the H Zone of the Pannonian in Austria (Eichkogel) and Slovakia (Čeľadince) only.

Genus *Armiger* HARTMANN, 1840
Type species *Nautilus crista* LINNÉ, 1758

***Armiger subptychophorus* (HALAVÁTS, 1911)**
(Pl. II, Fig. 3)

1911 *Planorbis subptychophorus* n. sp. - HALAVÁTS: p. 56, Pl. 3, Fig. 4
1911 *Planorbis subptychophorus* HALAVÁTS. - LÖRENTHEY: p. 113

Plate II

Fig. 1 *Segmentina loczyi* (LÖRENTHEY), Orešany, borehole PID-1 (36,5-36,6 m)
2 *Segmentina loczyi* (LÖRENTHEY), Orešany, borehole PID-1 (36,0-36,1 m)
3 *Armiger subptychophorus* (HALAVÁTS), Orešany, borehole PID-1(10,0-10,4 m)
4 *Segmentina filocincta* (SANDBERGER), Orešany-road cut
5 *Planorbarius thiollieri* (MICHAUD), Orešany, borehole PID-1 (36,0-36,1 m)

1953 *Planorbis (Gyraulus) subptychophorus* HALAVÁTS - SAUERZOPF: p. 56, Pl. 10, Fig. 4a-c
1959 *Gyraulus (G.) subptychophorus* (HALAVÁTS, 1903) - BARTHA: p. 78
1976 *Armiger subptychophorus* (HALAVATS) - SCHÜTT: p. 46, Pl. 7, Fig. 23

Material: 4 specimens from Orešany, borehole PID-1
Description: Halaváts (1911) p. 56
Occurrence in the Western Carpathians: Orešany, borehole PID-1 (22,0-22,1 m; 32,0-32,3 m; 36,5-36,6 m)
Stratigraphic range and geographic extension: The occurrence of this species is known from the Upper Pannonian of Hungary (Tihany, Kenese, Fonyód) and the H Zone of the Pannonian in Slovakia (Orešany).

Genus *Segmentina* FLEMING, 1817
Type species *Planorbis nitidus* MÜLLER, 1774

Segmentina loczyi **(LÖRENTHEY, 1911)**
(Pl. II, Fig. 1-2)

1911 *Planorbis (Segmentina) Lóczyi* nov. sp. - LÖRENTHEY: p. 119, Pl. 2, Fig. 18
1953 *Planorbis (Segmentina) loczy loczy* LÖRENTHEY - SAUERZOPF: p. 64, Pl. 4, Fig. 2a-c
1954 *Segmentina lóczyi* LÖRENT. - BARTHA: p. 178
1956 *Segmentina lóczyi* (LÖRENTHEY) - BARTHA: p. 517
1959 *Segmentina lóczyi* (LÖRENTHEY, 1906) - BARTHA: p. 79, Pl. 13, Fig. 3-5
1976 *Segmentina loczyi* (LÖRENTHEY) - SCHÜTT: p. 47, Pl. 7, Fig. 24

Material: 27 specimens from Orešany, borehole PID-1, 1 specimen from Orešany - road cut
Description: LÖRENTHEY (1911) p. 119
Occurrence in the Western Carpathians: Orešany, borehole PID-1 (9,8-10,0 m; 22,0-22,1 m; 32,0-32,3 m; 36,0-36,1 m; 36,5-36,6 m), Orešany - road cut
Stratigraphic range and geographic extension: The mentioned species is found in the H Zone of the Pannonian in Austria (Eichkogel), Slovakia (Orešany) and in the Upper Pannonian of Hungary (Öcs, Tihany, Fonyód, Várpalota, Balatonfüzfö, Tab).

Segmentina filocincta **(SANDBERGER, 1875)**
(Pl. II, Fig. 4)

1875 *Planorbis filocinctus* SANDB. - SANDBERGER: p. 714, Pl. 27, Fig. 10
1907 *Planorbis (Segmentina) filocinctus* SANDB. - SCHLOSSER: p.. 768, Pl. 17, Fig. 33

Material: 5 specimens from Orešany - road cut
Description: SANDBERGER (1875) p. 714
Occurrence in the Western Carpathians: Orešany - road cut
Stratigraphic range and geographic extension: This species is found in the H Zone of the Pannonian in Austria (Eichkogel) and Slovakia (Orešany).

Family *Ancylidae*
Genus *Acroloxus* BECK, 1837
Type species *Patella lacustris* LINNÉ, 1758

Acroloxus lacustris **(LINNE, 1758)**

1955 *Acroloxus lacustris* (LINNÉ, 1758) - LOŽEK: p. 369

Material: 1 specimen from Orešany, borehole PID-1
Description: Ložek (1955) p. 369
Occurrence in the Western Carpathians: Orešany, borehole PID-1 (32,0-32,3 m)
Stratigraphic range and geographic extension: The mentioned species has been known from the Pliocene and Quaternary of Europe so far only.

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The fossils in Pl. I Fig. 1 and 4 and Pl. II, Fig. 1, 5 were photographed by Mrs. C. Michalíkovou and other on SEM JEOL-840 at the Geological Survey of the Slovak republic (operator K. Horák).

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