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Metamorphic Sequences with "Bündnerschiefer" Lithology in the Pre-Neogene Basement of the East Slovakian Basin

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Metamorphe Abfolgen mit „Bündnerschiefer"-Lithologie im präneogenen Grundgebirge des Ostslowakischen Beckens

Zusammenfassung

Das präneogene Grundgebirge im ostslowakischen Anteil der transkarpatischen Depression besteht aus einer Schichtfolge von Kalkphylliten, phyllitischen Schiefern, graphitischen Schiefern (Schwarzschiefern), mergeligen Kalken, Metatuffiten etc., die in ihren oberen Anteilen in Sedimente mit zunehmendem Flyschcharakter übergehen (Iňačovce-Krichovo-Einheit). Sie enthalten alpinotype Ultrabasite mit unterschiedlichem Grad der Umwandlung, nämlich Peridotite, Lizardit-Chrysotil-Serpentinite, die bis zu Talk-Chlorit-Schiefern reichen.

Diese über 1000 m mächtige Schichtfolge reicht stratigraphisch vom obersten Paläozoikum über das Mesozoikum bis zum Eozän. Sie wurde durch nacheozäne Überschiebungen syntektonisch unter anchizonalen bis epizonalen Bedingungen metamorph und von Scherprozessen erfaßt, die an Hand von Schieferung, Streckungslineation, Crenulation und kräftiger Isoklinalfaltung erkannt werden können.

Diese dem Penninikum ähnliche Schichtfolge kommt in einem Bereich vor, in dem die subtatrische Deckenabfolge tektonisch durch die Mechanismen eines pull-apart-domes freigelegt wurde.

Abstract

The pre-Neogene basement in the East Slovakian part of the Transcarpathian Depression is built up by complexes of calcphyllites, phyllitic schists, graphitic schists (Schwarzschiefer), marbly limestones, metatuffites, etc., which, in the upper parts, pass into sediments that become more flysch-like in character (Iňačovce-Krichevo Unit). They contain Alpine-type ultrabasites with different degrees of alteration – peridotites, lizardite-chrysotile serpentinites up to talc-chlorite schists.

As for age, the over-a-thousand metre thick sequences belong to the Uppermost Paleozoic, Mesozoic till Eocene. The complexes were influenced by post-Eocene thrusting, syntectonic metamorphism under anchi/epizonal conditions, and shearing processes recognisable through a slate cleavage, stretching lineation, crenulations, strong isoclinal refolding, etc.

The described Penninic-like complexes occur in the space where the sub-Tatric nappe pile was tectonically unroofed by the mechanisms of a "pull-apart" dome.

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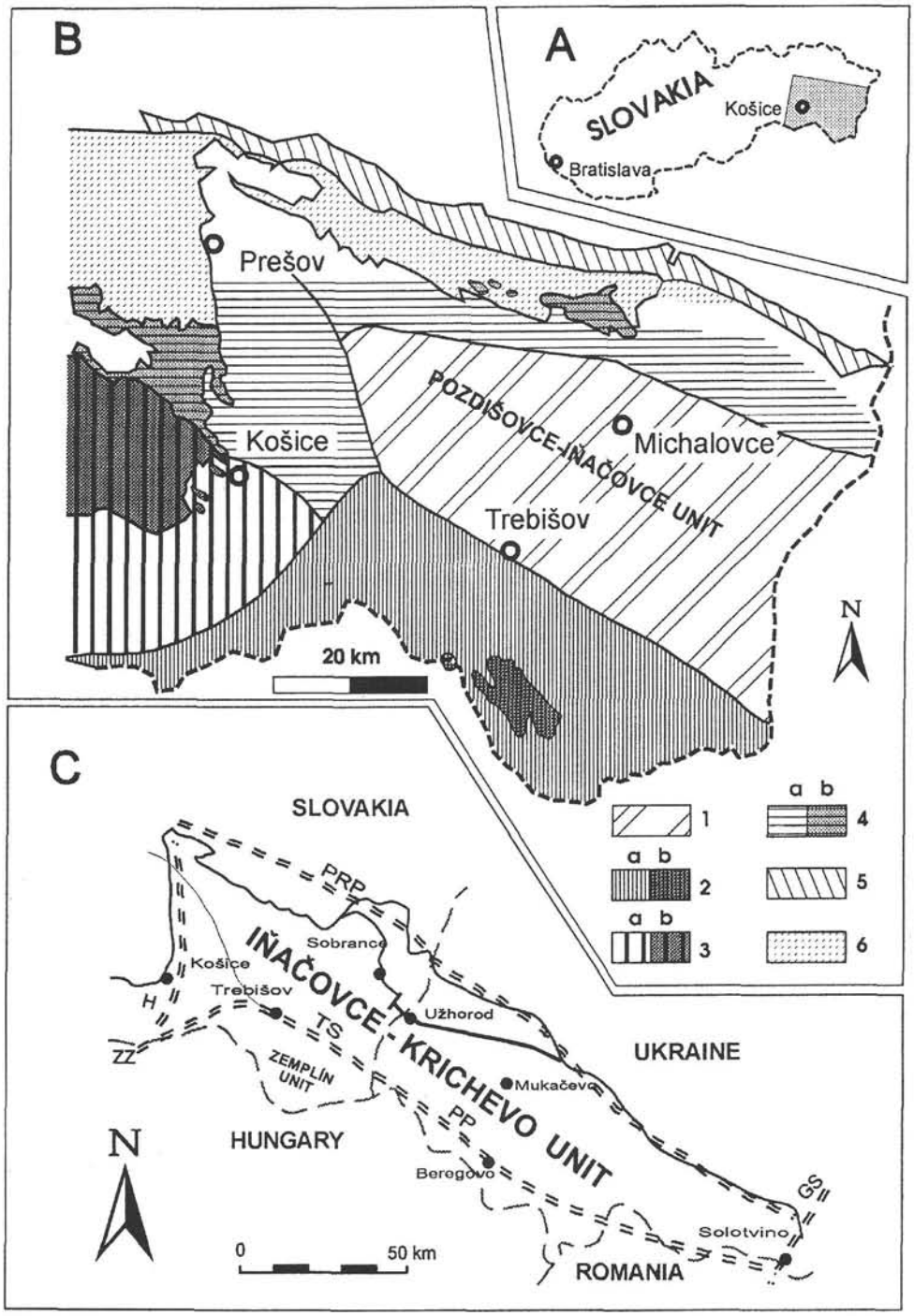
1. Introduction

In the transition zone of the Western and Eastern Carpathians, between the Hornád fault and the faults on the Ganichi-Solotvino line, the units of Central Carpathian sub-allochthon disappear in a coulisse-like way and lower structural units emerge. They form the basement of the Transcarpathian Depression which was being downfaulted between the Peri-Pieniny and Peri-Pannonian deep faults in Neogene time (Text-Fig. 1–C). Knowledge on the structure of these units was obtained from deep boreholes in Ukraine and Slovakia.

The basement of the East Slovakian basin is built up by the Zemplín block as well as the Pozdišovce-Iňačovce Unit (Text-Fig. 1–B). They are included in a higher-rank unit called Zemplinikum (SLÁVIK, 1976). The internal tectonic style of the Zemplinikum is characterized by the overthrusting of the Zemplín block on the Pozdišovce-Iňačovce Unit probably along the Trebišov–Szamos line (= Peri-Pannonian deep fault). The variable age estimations of the overthrusting range from Upper Cretaceous (GRECULA & EGYÜD, 1977), Laramian (RUDINEC, 1989) to Savian–Helvetian (ĎURICA, 1982). There are opinions that the Pozdišovce-Iňačovce Unit, in the basement of the Pieniny Klippen Belt, is overthrust on the outer flysch units and the southern edge of the North European platform (LEŠKO et al., 1977). The Pozdišovce-Iňačovce Unit, particularly its top part is overthrust by the sub-Tatric units of the Humenské pohorie Mts. (Krížna nappe). In the Neogene basement there is thus originating a morphological elevation called Humenné-Uzhgorod horst (RUDINEC, 1989a).

The substratum of the Transcarpathian Depression in the Ukraine territory is built up by the so-called Krichevo Unit exhibiting a number of stratigraphic and structural particularities.

They comprise a continuous Mesozoic through Paleogene sedimentary sequence characterized by untypical facies (for example Triassic limestones and dolomites associating with basic volcanics, Jurassic marlstones and sandstones containing posidonias and ammonites, Upper Cretaceous marlstones, siltstones and sandstones – thick Krichevo formation), block-sheet structure, absence of pre-



Text-Fig. 1.
Geological setting of the studied territory.
A) Selected area in Eastern Slovakia.
B) Basement units of the East Slovakian basin and units from adjacent areas.
1 = Pozdišovce-Iňačovce unit; 2 = Zemplinikum, a = in the basin basement, b = cropping out in the "Zemplín island"; 3 = Gemericum, a = in the basin basement, b = cropping out in the Spišsko-Gemerské rudohorie Mts.; 4 = Mesozoic cover nappes, a = in the basin basement, b = cropping out in the Čierna hora Mts. (W) and Humenské pohorie Mts. (NE); 5–Pieniny Klippen Belt, 6–Central Carpathian Paleogene.
C) Situational sketch of the Iňačovce-Krichevo unit within the basement units of the Transcarpathian Depression. H = Horn d fault, ZZ = Zagreb-Zemplín line, TS = Trebišov-Szamos line, PRP = Peri-Pieniny lineament, PP = Peri-Panonian fault, GS = Ganici-Solotvino fault; full line = Transcarpathian basin marigins and submerged horsts.

Senonian tectonic deformation and a post-Paleogene age of the major folding processes (SVIRIDENKO, 1976; SVIRIDENKO & SPITKOVSKAYA, 1979; PETRASHKEVITCH, 1971; etc.).

In spite of a similarity between the structures of the western and eastern parts of the Transcarpathian Depression, the stratigraphic assignment of the units on the Slovakian territory has been interpreted differently.

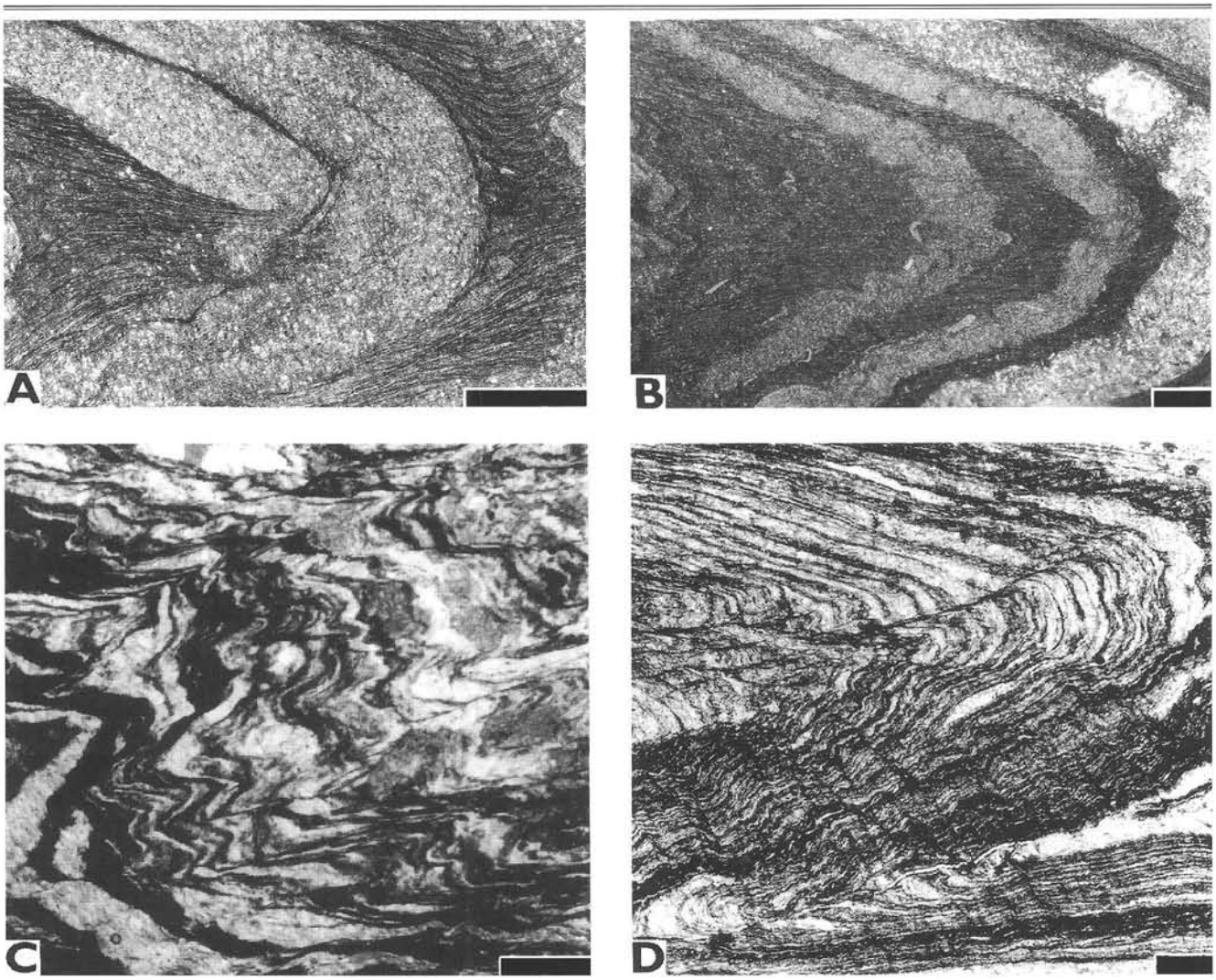
Especially with huge complexes of calcphyllites, graphitic and chloritic schists, metapsammites, marble limestones and metatuffites, building the Pozdišovce-Iňačovce Unit, only Upper-Paleozoic age has been considered (MAGYAR, 1976; RUDINEC, 1989). This is why the linking of the Pozdišovce-Iňačovce Unit with the Mesozoic-Paleogene sequences of the Krichevo Unit in the eastern part of the Transcarpathian Depression as a unified regional structure, the so-called Iňačovce-Krichevo Unit (ĎURICA, 1982), has not been supported by identical lithostratigraphic evidences.

The views were only changed by considering the Pozdišovce-Iňačovce Unit as one of the Western Carpathian equivalents of the Alpine Penninic units (LEŠKO et al., 1977; LEŠKO & VARGA, 1980). Possible presence of the Penninic-like metamorphosed sequences with ophiolites in the complexes of the Pozdišovce-Iňačovce Unit was also pointed out by MAHEL' (1988).

These considerations were also initiated by a considerable extension of the bodies of ultrabasic rocks within the Pozdišovce-Iňačovce Unit which are suggested by magnetic anomalies and confirmed in several boreholes (MOŘKOVSKY & ČVERČKO, 1987; GNOJEK et al., 1991; GNOJEK, 1987; etc.).

The paper presents new data on the character of the pre-Neogene basement of the East Slovakian basin (Pozdišovce-Iňačovce Unit), that are complementary to the knowledge from the Krichevo Unit. Such are facts proving the presence of Permomesozoic to Paleogene sediments in the complexes of both the units and their similar structure overprinted by Alpine low-grade metamorphism, thrusting and stretching.

Thus, in the Transcarpathian Depression basement a higher-rank unit has been defined, already in the past called the Iňačovce-Krichevo Unit (Text-Fig. 1–B).



Text-Fig. 2.
Lithology and deformational structures of the "Bündnerschiefer"-like metasediments in the Pozdišovce-Iňačovce Unit.
A,B) Folded metasiltstones overprinted by penetrative crenulation cleavage in metapelitic bands.
Iňačovce-3 borehole (2215–2220 m). Scale bars = 1 mm (plane-polarized light).
C) Zig-zag folding of the phyllitic marble.
Rebrín-1 borehole (3575–3578 m). Scale bar = 0,5 mm (plane-polarized light).
D) Small-scale fold in graphitic phyllite.
Iňačovce-1 borehole (3349–3354 m). Scale bar = 1 mm (plane-polarized light).

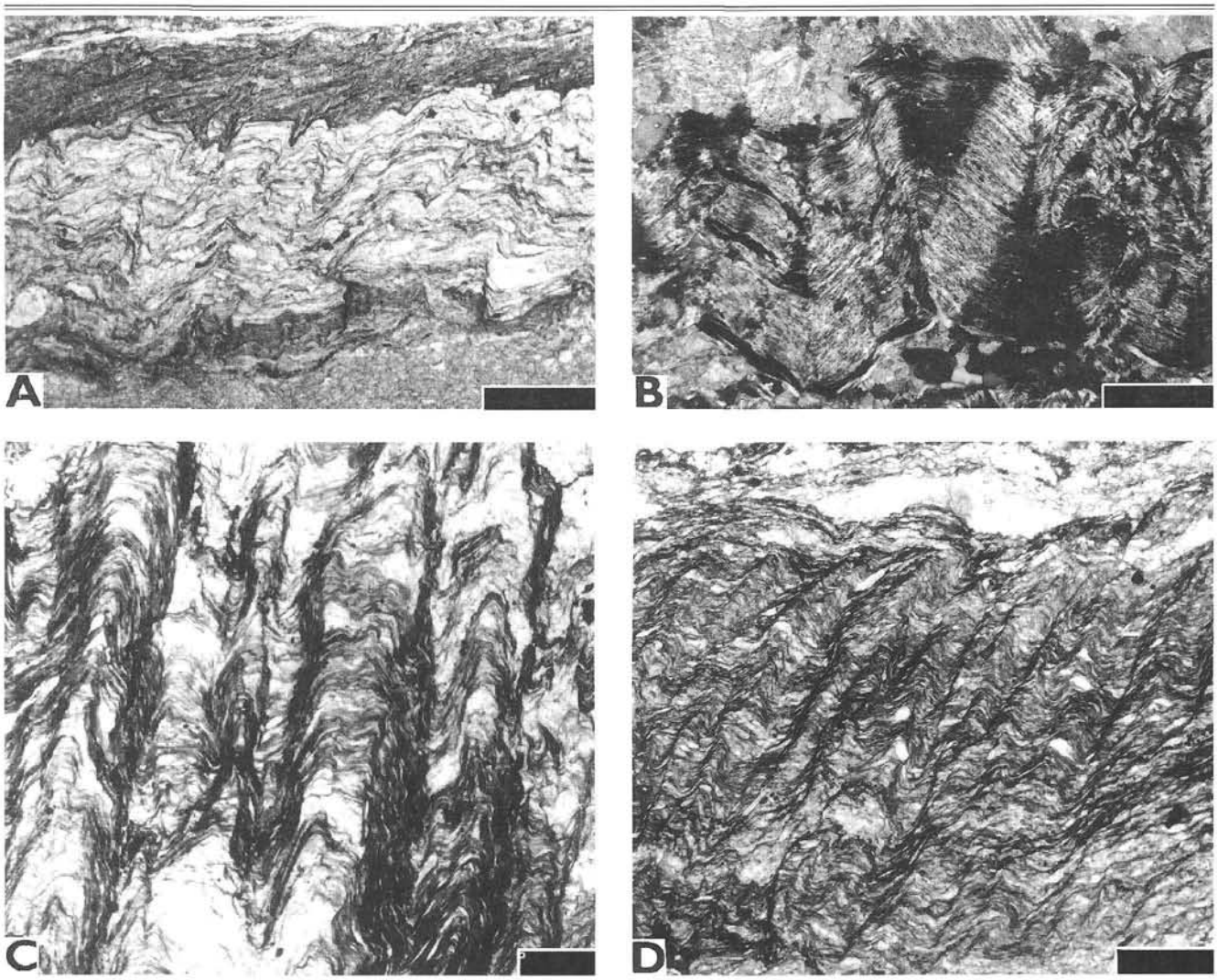
2. Metasediments with "Bündnerschiefer" Lithology in the Pozdišovce-Iňačovce Unit

In the rock complexes of the Pozdišovce-Iňačovce Unit there are calcphyllites, phyllitic schists, graphitic schists (Schwarzschiefer), marble limestones, metasandstones, metasiltstones, metatuffites, etc. Biostratigraphic data gave only an Upper Triassic age for the marbles which are located in the lower part of metasedimentary formations (foraminifers – Text-Fig. 4–A).

Above the Upper Triassic marbles follow variegated, reddish and purple schists which in the Penninic units usually represent red-bed formations called as "Quartenschiefer" (FREY, 1974). In the upper course there are thick complexes of dark shales with "Bündnerschiefer" lithology, the age of which is estimated Jurassic. Locally they are intercalated with ochre-yellow finely laminated limestones bearing crinoidal detritus.

The Cretaceous is probably represented by turbiditic sequences of dark shales and metasandstones containing spinel detritus. As a whole, the complexes of the Pozdišovce-Iňačovce Unit are very poor in fossils. However, this fact itself points out the similarity of the Pozdišovce-Iňačovce rock complexes to the formations of the Penninic units of the Alps. We will only focus on the metamorphosed Mesozoic Bündnerschiefer formations, which, in spite of a long tradition of research, are stratigraphically dated only with palynomorphs (PANTIC & GANSSER, 1977; PANTIC & ISLER, 1978). On the contrary, faunistic sterility is given as one of the characteristic features of this most common formation of the middle and northern Penninicum (WILDI 1988).

The phenomena observed in the rock complexes of the Pozdišovce-Iňačovce Unit – such as low-grade metamorphism reaching the formation of muscovite, paragonite, mixed-layer paragonite/muscovite, chlorite, pyrophyllite, chloritoid, quartz, albite, carbonates, etc., silky lustre, strong stretching lineation and other deformation elements (especially crenulations), high content of organic substance and pyrite, Na-metasomatic effects (K-feldspar albitization), presence of allodapic detritus (crinoidal particles, echinoid spines – Text-Fig. 4–B,C), faunistic sterility, pyroclastic



Text-Fig. 3.
A) Mica flake within the phyllitic marble.
Blatná Polianka-3 borehole (2095–2100 m). Scale bar = 0,5 mm (plane-polarized light).
B) Marble with the mica-rich intercalation which is deformed as a kink bands.
Blatná Polianka-1 borehole (1297–1309). Scale bar = 0,25 mm (crossed polars).
C) Strongly deformed phyllite showing the segmentation to the cleavage microlithons.
Senné-8 borehole (3495–3500 m). Sale bar = 0,5 mm (plane-polarized light).
D) Crenulated phyllites from the Zbudza-1 borehole where they are interlayered with Nummulites-bearing metasandstones.
Depth 3118–3122 m. Scale bar = 0,5 mm (plane-polarized light).

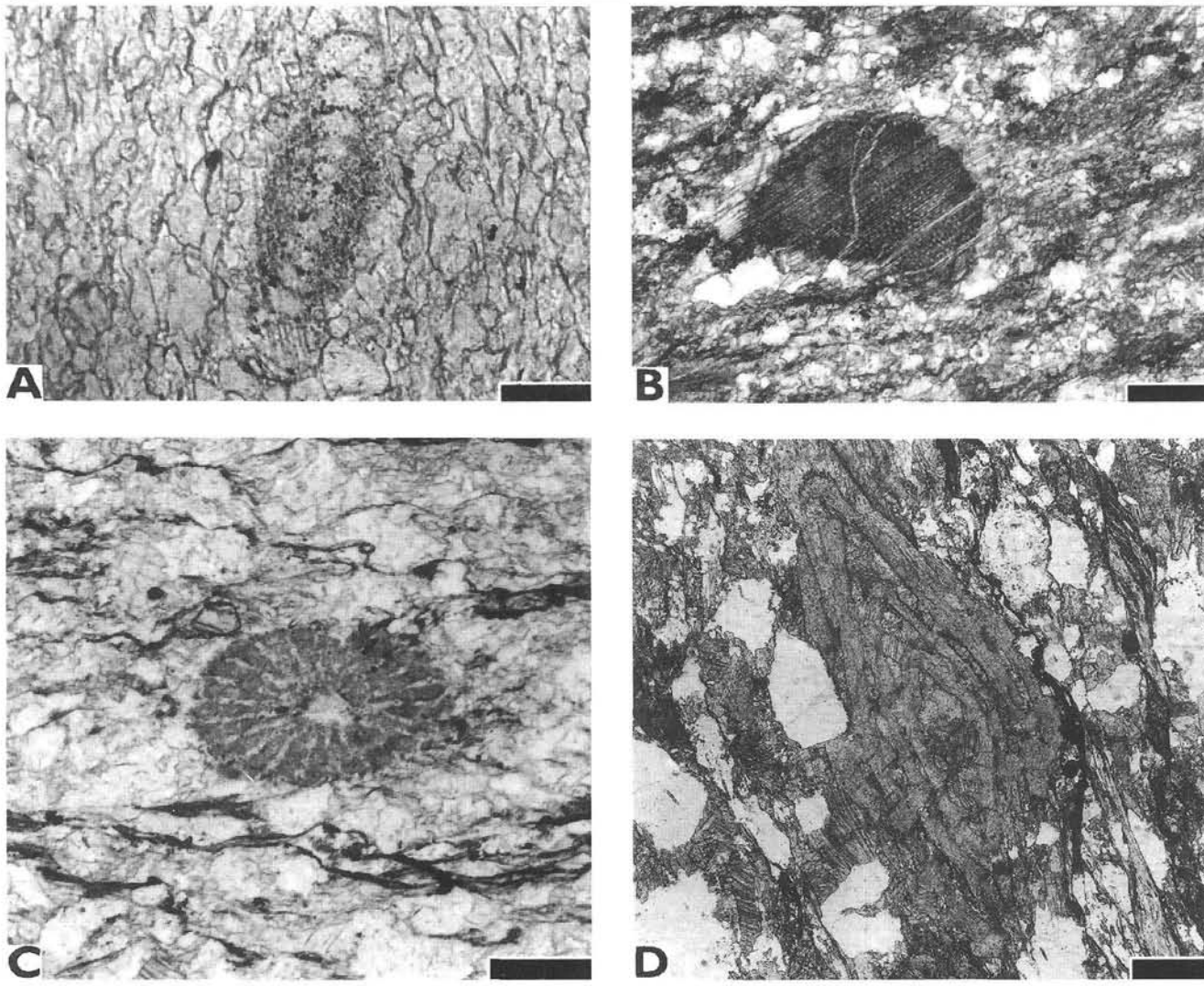
admixture, etc. – are characteristic for the Bündnerschiefer – Schistés lustré metasediments (cf. FREY, 1974; AYRTON & RAMSAY, 1974; ELSNER, 1991; WILDI, 1988; etc.). Monotonous sequences of these rocks in the Pozdišovce-Iňačovce Unit, like in the Penninic units, were originating by a long-term accumulation of calciclastic and silicoclastic fine-fractionated turbidites ("flysch schisteux", "pre-flysch"). A sedimentary model of the Bündnerschiefer facies origin takes into account their deposition in deep-water distal conditions of extensional basins (WILDI, 1988; FRISCH et al., 1987).

3. Metamorphosed Eocene Flysch Sequences in the Pozdišovce-Iňačovce Unit

The youngest sediments of the Pozdišovce-Iňačovce Unit were drilled in the northern part of the East Slovakian basin, and that was below serpentinite bodies. They are a formation of black shales and sandstones showing signs of flysch lithofacies. The Eocene age of the formation has been determined according to nummulites and other large foraminifers (Text-Fig. 4D).

The described Eocene sediments are considerably folded and dynamometamorphosed. Their metamorphic alteration reached the grade of phyllitic rocks according to the presence of paragonite (cf. PAMIC et al., 1992). They have identical deformation styles such as schistosity, stretching lineation, crenulations, boudinage and breaking competent siltstone and sandstone layers, pressure shadows, etc. (Text-Fig. 3–D) compared with the older rock complexes of the Pozdišovce-Iňačovce Unit.

Tectonometamorphism in the Eocene formations of the Pozdišovce-Iňačovce Unit proves very young Neoalpine age of its final phases. Eoalpine tectonics, generally associated with shifting the Central Carpathian nappes, is in the



Text-Fig. 4.
Fossil remains recorded in the metasediments of the Pozdišovce-Iňačovce Unit.
A) Foraminiferal test preserved in the marble from the Upper Triassic red-bed formation. On the test there are identifiable signs of the *Aulotortus communis* species.
Bunkovce-1 borehole (1822–1826 m). Scale bar = 0,1 mm (plane-polarized light).
B) Recrystallized crinoidal particle within detrital components of calcareous metasandstone.
Lesné-2 borehole (3014–3099 m), Scale bar = 0,25 mm (plane-polarized).
C) Echinoid spine in the marble limestones from the Iňačovce-3 borehole (2667–2671 m).
Scale bar = 0,25 mm (plane-polarized light).
D) Large foraminifera preserved as a rigid component in the metasandstone. It attributes to the *Nummulites gallensis* species.
Zbudza-1 borehole (3702–3705 m), Scale bar = 0,5 mm (plane-polarized light).

complexes of the Pozdišovce-Iňačovce unit either overprinting by Neoalpine tectonics or missing. With post-Eocene folding and metamorphic alteration, as well as age, lithological character and likely continuity with older sequences bearing ophiolite rocks, the Eocene flysch in the East Slovakian basin basement is comparable to the sediments of the Krichevo Unit as well as to the Penninic units (the youngest sediments in the Penninic windows, e.g. in Engadine window, are also Eocene sediments – OBERHAUSER, 1983).

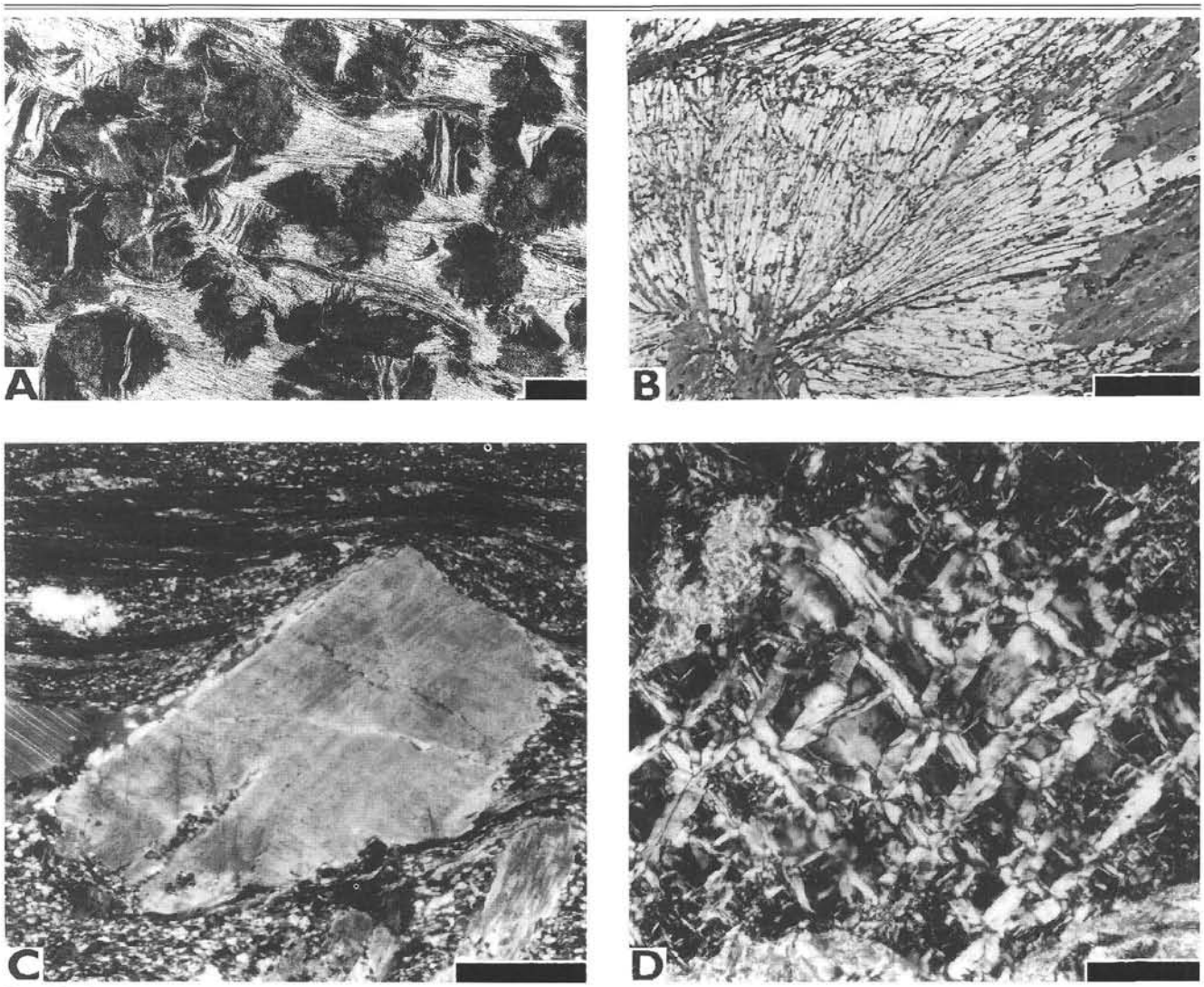
The Eocene sediments participation in the sheet-overthrust structure of the East Slovakian basin basement justifies the considerations on a double-level Periklippen Paleogene of the Šambron-Kamenica belt (RUDINEC, 1989b), which, according to some authors, is not an integral part of the Central Carpathian Paleogene, but a pendant of the Krichevo unit and the Debrecen-Szolnok belt (LEŠKO et al., 1977; GRECULA et al., 1981).

There are ultrabasic rock bodies tectonically superimposed on the described Eocene formations. Several possible interpretations can be given for their relationship:

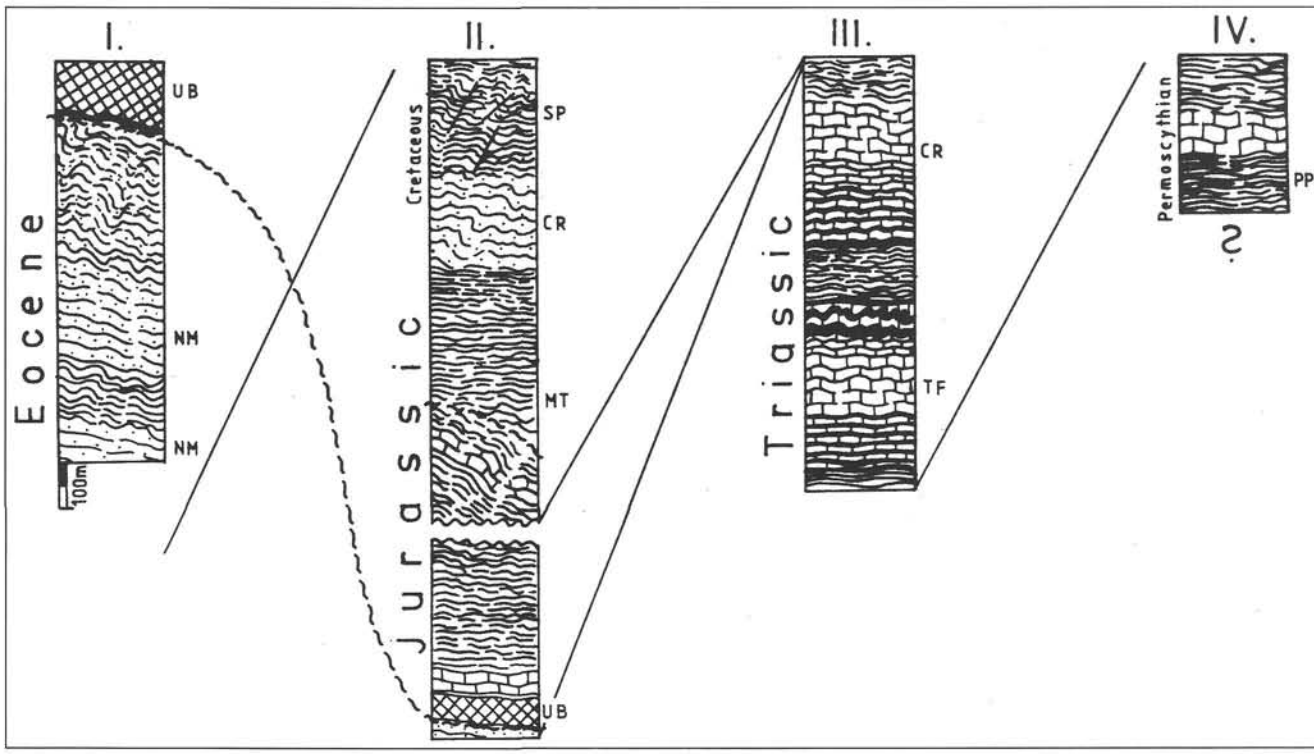
1) ultrabasic protrusions from the older complexes of the Pozdišovce-Iňačovce Unit along structural discontinuities (e.g. on the Zbudza–Uzhgorod fault);
2) denudation remains of an extended overthrust or strike-slip duplex;
3) penetrations from the mantle under a Neogene thermal subsidence and opening the East Slovakian basin by a "pull-apart" mechanism (VASS et al., 1988).

4. Ultrabasic Bodies, Volcanic Rocks and Volcanoclastic Horizons in the Complexes of the Pozdišovce-Iňačovce Unit

The presence of ultrabasic rock bodies in the complexes of the Pozdišovce-Iňačovce Unit is indicated by extended magnetic anomalies with peaks near Sečovce and Zbudza-Nacina Ves (MOŘKOVSKÝ & ČVERČKO, 1987; GNOJEK, 1987;



Text-Fig. 5.
A) Chloritoid schists with rosette-like chloritoid porphyroblasts which show syngenetic formation with s_1 planes. Senné-2 borehole (3282–3282,5 m). Scale bar = 0,5 mm (plane-polarized light).
B) BSE image of chloritoid porphyroblast showing the radial-fibrous structure. Iňačovce-3 borehole (3000-3004,5 m). Scale bar = 0,1 mm.
C) Metatuffite with pre-s_1 generated plagioclase crystaloclasts. Iňačovce-3 borehole (3110–3115 m). Scale bar = 0,5 mm (plane- polarized light).
D) Mesh texture of lizardite-chryzotile serpentinite from the Senné-8 borehole (3434,5–3436 m). Scale bar = 0,3 mm (crossed polars).



Text-Fig. 6.
Lithostratigraphic interpretation of the borehole profiles from the complexes of the Iňačovce-Krichevo Unit on the Slovak territory.
I) Thin rhythmically-bedded flysch tectonically overthrust by ultrabasites (UB = ultrabasites, NM = nummulites, wavy line = overthrust plane).
II) Pelitic-aleuritic cycles of the Cretaceous flysch (with spinel detritus = SP) and shaly-turbiditic sequences of Bündnerschiefer-type (CR = crinoidal detritus, MT = metatuffites, UB = ultrabasites).
III) Complexes of marble limestones and calcphyllites (Cr = crinoidal detritus, TF = Triassic foraminifers of the genera Permodiscus-Aulotortus).
IV) Complex of phyllitic schists, calcschists and marble limestones (PP = Upper Permian palynomorphs).

GNOJEK et al., 1991; etc.). They were also confirmed in five deep boreholes. The ultrabasic rocks include serpentinized peridotites with preserved primary minerals such as olivine, clinopyroxene, orthopyroxene, chromian spinel and lizardite-chrysotile serpentinites with relict structures (Text-Fig. 4–D), up to strongly altered talc-chlorite-tremolite-carbonate rocks. According to their primary minerals (olivine Fo_{90}, orthopyroxene, clinopyroxene) these rocks originate from the upper mantle and often form lower parts of ophiolite complexes (COLEMAN, 1977). Spinels from the ultrabasites of the Pozdišovce-Iňačovce Unit are in Cr/Mg plot (DICK & BULLEN, 1984) concentrated in the abyssal peridotites field, and/or in ternary plot Cr-Al-Fe^{3+} in the residual peridotites (ophiolites) field (JAN & WINDLEY, 1990). Their zonal character (Mg-rich chromian spinel core with ferrichromite rim) together with variable compositions of grains can be attributed to the alteration processes of greenschist facies. Similar chemical composition can be also seen with spinels from the Penninic metaultramafites in the Tauern and Unterengadine windows (cf. POBER & FAUPL, 1988).

In the rock complexes of the Pozdišovce-Iňačovce Unit there were also recorded volcanic rocks and volcanoclastic horizons. They are represented by metabasalts, basic more metatuffites (rock with Mg-chlorite base and residues of mafic minerals – titanite, rutile) and acidic metatuffites (rocks with porphyroclasts of checked albite, quartz and K-feldspars overgrowth to new crystal forms – Text-Fig. 4–C).

The scope of ultrabasic and volcano-sedimentary rock occurrences in the complexes of the Pozdišovce-Iňačovce Unit has the character of a clear-cut intrusive-effusive record. With ultrabasic and volcanoclastic rock occurrences, the complexes of the Pozdišovce-Iňačovce Unit are comparable with the Penninic formations specific for ophiolite associations (DIETRICH et al., 1974; HÖCK & MILLER, 1987; etc.). On the other hand, basic intrusions and effusions have been also reported from the Mesozoic formations of the Transcarpathian area (diabases, spilites, diabase porphyrites, tuffs and tuffites of the Krichevo Unit – SVIRIDENKO, 1976).

During the formation of thrust structures in the complexes of the Pozdišovce-Iňačovce Unit were formed planes of décollement in ductile ultrabasic rocks. Sheet overthrusting with tectonic superposition of the Mesozoic complexes cutting off in ultrabasic bodies on the Paleogene formations was also confirmed in borehole Pavlovce-1.

5. Overthrusting of the Pozdišovce-Iňačovce Unit by the Centrocarpathian Nappes and its Extensional Unroofing

The complexes of the Pozdišovce-Iňačovce Unit are in places superimposed by remnants of sub-Tatric nappes (Gutenstein limestones and dolomites in the tectonic roof of typical formations of the Pozdišovce-Iňačovce Unit in the borehole Hrušov-1).

This clearly shows that the Pozdišovce-Iňačovce Unit takes a lower and that is more external position than sub-Tatric and perhaps Tatric units. The situation here is similar to the Penninic units overthrusting by Unterostalpine nappes.

The uncovering of the Pozdišovce-Iňačovce Unit was not taking place through erosional cutting off nappe pile, but through tectonic unroofing. Large-scale shear zones trending in Carpathian direction in combination with oblique fault lines formed a conjugate system of a "pull-apart" dome here (cf. GENSER & NEUBAUER, 1989). The unroofing of the Pozdišovce-Iňačovce Unit in the area of the East Slovakian basin was thus controlled by the same mechanisms as the exhumation of the Penninic windows of the Alps (lateral extrusion, wrench corridors, "pull-apart" metamorphic domes see RATSCHBACHER, 1986; RATSCHBACHER et al., 1990, 1991; GENSER & NEUBAUER, 1989; etc.). With unroofing of the Pozdišovce-Iňačovce Unit, "pull-apart" activity was accompanied by extensive subsidence of the East Slovakian basin up to Middle Miocene; as late as in the Badenian sediments there are lots of strain phenomena developed (stretching lineations).

6. Structural-Deformation Effects and Alpine Metamorphism in the Complexes of the Pozdišovce-Iňačovce Unit

The major structural pattern of the complexes from the Pozdišovce-Iňačovce Unit is s_0 planes (pseudo-bedding) showing a distinct stretching lineation l_1 and silky lustre. The so planes are at a small angle cut through by slaty cleavage s_1 planes which are bearers of mineral lineation l_2. The most typical phenomenon of deformation of these rocks is a cleavage segmenting and crenulating planary s_0 and s_1 elements (crenulation cleavage – Text-Fig. 3–C). Ductile deformation is present in the form of various folds in the complexes of the Pozdišovce-Iňačovce Unit (Text-Fig. 2 A-D). In metapelitic sequence, intrafolial isoclinal, zig-zag, chevron and rootless folds are dominating. In more competent metasandstone formations there are by and large concentric, composite and disjunctive mesofolds. The effects of grain-size deformations are manifested mainly through pressure shadows, pounding clastic particles in the mylonitic foliation ("Augengefüge"), pressure solution, dynamic recrystallization (banded quartz – "Bänderquartzgefüge"), pressure microfolds and undulosity, grain rotation, bending twin lamellae of calcite crystals, cross-mica formation, phylosilicate kink bands (Text-Fig. 3–B), etc.

Kinematic analysis of these deformations points out compressive, extensive and shear processes in the complexes of the Pozdišovce-Iňačovce Unit. The described deformations are a result of syntectonic compaction and metamorphism (s_0 planes, slaty cleavage, parakinematic crystallization of minerals, l_1 mineral lineation), later extension (extensional crenulation cleavage, stretching lineation, isoclinal refolding, conjugate systems of extensional calcite veinlets) passing to a horizontal shearing (intrafolial boudins and folds, mylonitic foliation, rotated grains, asymmetric pressure shadows, shear bands) even to a shear on fault planes (fault striae – slickenside lineations).

The kinematic history of the Alpine deformation in the Pozdišovce-Iňačovce Unit is comparable with structural evolution of the Penninic units in the Alps (see RING et al., 1989, 1991; MANCKTELOW, 1985; MERLE et al., 1989; etc.). Similarity of deformation styles of these units can be mainly seen from dense systems of crenulation cleavage. This type of cleavage is a result of deformation of metasediments rich in phyllosilicates at temperatures about 300°C (VOLL, 1980).

The Pozdišovce-Iňačovce Unit is built up by metasediments from low metamorphic facies. In their mineral assemblages the following components were identified: quartz, muscovite (solely polytype $2M_1$), chlorite, mixed-layer paragonite/muscovite (hereinafter P/M), paragonite, calcite, albite, pyrophyllite, organic matter, kaolinite, dolomite, siderite, pyrite, hematite, chloritoid (Text-Fig. 4–A,B), rutile, apatite, tourmaline, corrensite and mixed-layer illite/smectite.

From the point of view of physical conditions of metamorphism the present mineral assemblages can be divided into two groups. The first group is represented by the non-diagnostic assemblages with major abundance; it is comprised of the following assemblages: muscovite + P/M + paragonite + quartz ± albite ± organic matter. These assemblages are stable under sub-greenschist facies as well as greenschist facies conditions (FREY, 1988).

The second group consists of assemblages scarcely ascertained, but it enables more exact determination of metamorphic conditions. They are: muscovite + paragonite + pyrophyllite, chlorite + chloritoid and chloritoid + pyrophyllite. Pyrophyllite is a product of kaolinite dehydration at temperatures between 280–330°C (FREY, 1987). Chloritoid is very likely to have been formed according to the reaction: pyrophyllite + chlorite ⇒ chloritoid + quartz + H_2O (ZEN, 1960), with stability falling within temperatures 400–435°C, in terms of thermodynamic calculations by BALTATZIS (1980). There is an inevitable condition of the assumed reaction that temperature does not reach the breakdown point of pyrophyllite which comes at a temperature between 387–420°C (SPEAR & CHENEY, 1989; BERMAN et al., 1985; CHATTERJEE et al., 1984).

Pressure conditions of metamorphism have not been exactly specified yet for neither the general bulk of metasediments nor the mineral assemblages are suitable for using b_0 parameter of K-muscovites (see GUIDOTTI & SASSI, 1976). However, the presence of chloritoid + pyrophyllite assemblages indicates conditions corresponding to the interval of low–middle pressures of lower greenschist facies (WINKLER, 1979; CHOPIN & SCHEYER, 1983).

The above mentioned facts suggest that maximum temperatures of metamorphism were between 300–400°C, at expected low or middle pressures. Contingent variations of metamorphic conditions towards lower temperatures can be neither denied nor proved as omnipresent paragonite makes it impossible to apply the method of illite "crystallinity". However, the presence of this mineral as a separate phase suggests that the metamorphism reaches at least the middle degree anchizonal conditions (e.g. MERRIMAN & ROBERTS, 1985).

7. General Conclusions

The Iňačovce-Krichevo Unit, forming a major part of the Transcarpathian Depression basement, is made up by complexes with some similarities of the Penninic zone:

* There are monotonous sequences of fine turbiditic sediments of "Bündnerschiefer" type with ultrabasic bodies, volcanic rocks and volcanoclastic horizons, and thin rhythmically-bedded Upper Cretaceous? and Eocene flysch.
* The Iňačovce-Krichevo Unit has an overthrust structure combined with shearing; the Permomesozoic through Eocene sediments participate in it. Its rock complexes were anchizonally/epizonally metamorphosed, consider-

ably folded and stretched during post-Eocene tectonogenesis.

* Within the structural plan of the Western Carpathians the paleotectonic element of the Iňačovce-Krichevo Unit responds to hypothetical Vahicum (= unspecified Penninicum). Lithological filling (Bündnerschiefer formations), Neoalpine character of the deformation and metamorphism and extra-Tatric position of the Pozdišovce-Iňačovce Unit rather support its North Penninic origin.
  Uncovered parts of the Penninicum occurred only in the terminal blocks of the Western Carpathians, e.g. in lowermost units of the Malé Karpaty Tatricum (MAHEL' 1983, PLAŠIENKA et al., 1991) and behind the Hornád fault. Tectonic unroofing of the Penninic sequences in the East Slovakian basin area was a result of a strong extension on the conjugate system of shear zones and fault lines. Like in the Penninic windows of the Alps, there was exhumed a "pull-apart" dome here with the most distinct crustal thinning and highest thermal gradient in the Western Carpathians (FUSÁN, 1985; POSPIŠIL & BODOKY, 1981; ČERMÁK, 1979). "Pull-apart" processes also controlled the opening of the basin itself during molasses sedimentation (VASS et al., 1988).
* The Iňačovce-Kričevo Unit continues to the Periklippen zone (Šambron-Krichevo belt according to GRECULA et al., 1981), which is regarded as a higher structural etage of the subducted Vahicum (MAHEL' 1988). The Penninic segments with a seismic appearance similar to that of the Iňačovce-Krichevo Unit (distinct seismic anisotropy with subhorizontal reflections due to schistose character of rock complexes) lie under the Tatro-Veporic crystalline basement nappes in 2–6 km depth (TOMEK et al., 1989; TOMEK – personal contact).

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