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THE PENNINIC "PULL-APART" DOME IN THE PRE-NEOGENE BASEMENT OF THE TRANSCARPATHIAN DEPRESSION (EASTERN SLOVAKIA)

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Abstract: Pre-Neogene basement in the East Slovakian part of the Transcarpathian Depression is built by complexes of calcphyllites, phyllitic schists, graphitic schists (Schwarzschieferhorizonten), marbly limestones, metatuffites, etc., which, in the upper parts, pass into the sediments that become more flysch-like in character (Iňačovce-Krichevo unit). They contain Alpine-type ultrabasites on different degrees of alteration - peridotites, lizardite-chrysotile serpentinites up to talc-chlorite schists. As for age, these over a thousand metre thick sequences belong to Uppermost Paleozoic, Mesozoic till Eocene. The complexes were influenced by post-Eocene thrusting, syntectonic metamorphism under anchi/epizonal conditions, and shearing processes recognizable through a slate cleavage, stretching lineation, crenulations, strong isoclinal overfolding, 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.

Key words: Eastern Slovakia, Iňačovce-Krichevo unit, Bündnerschiefer-like sequences, ultrabasites, post-Eocene dynamometamorphism, "pull-apart" unroofing.

Introduction

In the boundary 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 units of specific development emerge. They form the basement of the Transcarpathian Depression which was being downfaulted between the Peri-Pieniny and Peri-Pannonian deep faults in the Neogene period. Knowledge on the structure of these units was obtained from deep boreholes in Ukraine and Slovakia.

The substratum of the Transcarpathian Depression in the Ukraine territory is built by the so-called Krichevo unit special for a number of particularities from the point of view of stratigraphic development as well as structure. They comprise a continuity of the Mesozoic even Paleogene sedimentary sequences developed in untypical facies (limestone-dolomitic facies + basic rocks in the Triassic, marlstone- sandstone facies with posidonias and ammonites in the Jurassic, marlstone-siltstone-sandstone facies in the Upper Cretaceous - thick Krichevo formation, gravellite, marlstone and sandstone facies with tuffs and tuffites in the Paleogene), block-sheet structural character, absence of the pre-Senonian tectonic deformations and the post-Paleogene age of the major folding processes (Sviridenko 1976; Sviridenko & Spitkovskaya 1979; Petrashkevitch 1971, etc.).

The structure of the pre-Neogene basement of the Transcarpathian Depression on the Slovakian territory is formed by the Zemplín block with the Ptrukša zone as well as the Pozdišovce-Iňačovce unit. They are included in a higher-rank unit called Zemplinicum (Slávik 1976). The internal tectonic style of the Zemplinicum 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 age of this overthrust is estimated differently, as Upper Cretaceous according to Grecula & Együd (1977), Laramic according to Rudinec (1989) and Savian or Helvetian according to Ďurica (1982). Leško et al. (1977) support the opinion that the Pozdišovce-Iňačovce unit, in the basement of the Pieniny Klippen Belt, is overthrusted on the outer flysch units and the southern edge of the North-European platform. The Pozdišovce-Iňačovce unit, particularly its top parts is overthrusted 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 1989).

In spite of a similarity between the structures of the western and eastern parts of the Transcarpathian Depression, the stratigraphic attribution of the units on Slovak territory has been interpreted differently. Especially with huge complexes of calcphyllites, graphitic and chloritic schists, metapsammites, marbly limestones and metatuffites, building the Pozdišovce-Iňačovce unit, no but the Upper Paleozoic age has been considered. This is the reason 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 and that is by a unified regional structure, the so-called Iňačovce-Krichevo unit (Ďurica 1982), could not be supported by facts of identical lithostratigraphic development. The views were only changed by considering the Pozdišovce-Iňačovce unit 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 Pozdišovce-Iňačovce unit was pointed out by Maheľ (1988). These considerations were also initiated by a considerable extent of the bodies of ultrabasic rocks within the Pozdišovce-Iňačovce unit which are suggested by magnetic anomalies and confirmed in several boreholes (Mořkovský & 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 zone), that are complementary to the knowledge from the Krichevo zone. Such are facts proving the presence of the Permo-Mesozoic to Paleogene sediments in the complexes of both the zones and their similar structure overprinted by post-Eocene 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 (Fig. 1).

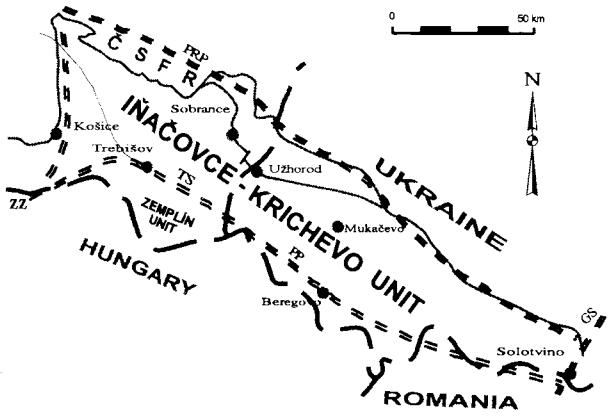


Fig. 1. Situational sketch of the Transcarpathian Depression with units participating in the structure of its pre-Neogene basement.
H - Hornád fault; ZZ - Zagreb-Zemplín line; TS - Trebišov-Szamos line; PP - Peri-Pannonian fault; GS - Ganichi-Solotvino fault

Bündnerschiefer metasediments in the Pozdišovce-Iňačovce zone

In the rock complexes of the Pozdišovce-Iňačovce zone there are calcphyllites, phyllitic schists, graphitic schists (Schwarzschieferhorizonten), silty-marbly limestones, siltstones, sandstones, metatuffites, etc. As for the age of these metasedimets there have been obtained biostratigraphic data on the Upper Triassic age of marbly limestones on the basis of formations (they contain foraminifers of *Permodiscinae-Aulotortinae* subfamily). Over the Upper Triassic carbonates there is found a set of variegate, redish and red-purple schists which in the Bündnerschiefer formations usually represent the Liassic. In the upper courses there are occurrences of ochre-yellow fine laminated limestones with an admixture of crinoidal detritus which are considered Upper Jurassic. The Cretaceous is probably represented by turbiditic sequences of dark marlstones and sandstones (they are typical for the presence of spinel detritus). As a whole, the complexes of the Pozdišovce-Iňačovce zone are very poor in fossils. Howewer, this fact itself poits out the similarity of the Pozdišovce-Iňačovce rock complexes to the formations of the Penninic units of the Alp. 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 scaly phylosilicates, chlorite, pyrophyllite, chloritoid, phengite, tourmaline (Turmalinblasten), silky luster and scrapping, strong lineation and other deformation elements (especially crenulations), high content of organic substance and pyrite, Na-metasomatic effects (K-feldspar albitization, spine-like aggregates of crocidolite, etc.), presence of allodapic detritus (crinoidal particles, echinoid spines), faunistic sterility, pyroclastic admixture, etc. - are characteristic of the Bündnerschiefer - Schistés lustré metasediments. Monotonous sequences of these rocks in the Pozdišovce-Iňačovce zone, like in the Penninic units, were originating by a long-term accumulation of calciclastic and silicoclastic fine-fractionated turbidites ("flysch schisteux", "pre-flysch"). Sedimentary model of the Bündnerschiefer facies origin takes into account their deposition in deep-water distal conditions of extensional basin (Wildi 1988; Frisch et al. 1987).

Eocene dynamometamorphosed sequences in the Pozdišovce-Iňačovce zone

The youngest sediments of the Pozdišovce-Iňačovce zone were bored in the northern part of the East Slovakian Basin, and that was under serpentinite bodies. They are a formation of black pelites and sandstones showing signs of flysch lithofacies. The age of the formation is estimated Eocene, according to nummulites and other large foraminifers. The described Eocene sediments are considerably overfolded and dynamometamorphosed. They have identical deformation styles (strong stretching lineation, crenulations, boudinage and breaking competent siltstone and sandstone layers, pressure shadows, etc.) with the older rock complexes of the Pozdišovce-Iňačovce zone. This suggests that they are continuous stratigraphic formations affected by a single tectono-metamorphic process after the Eocene. With its post-Eocene folding and dynamometamorphic 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 close to the sediments of the Krichevo unit and Penninic units (the youngest sediments in the Penninic windows, e.g. in Engadine one, 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 1989), 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. There are several possible interpretations of their relationship - ultrabasic protrusions from the older complexes of the Pozdišovce-Iňačovce zone along structural discontinuities (e.g. on the Zbudza-Uzl.gorod fault), denudation remains of an extended overthrust or strike-slip duplex, penetrations from the mantle under a Neogene thermal subsidence and opening the East Slovakian Basin by "pull- apart" mechanism (Vass et al. 1988).

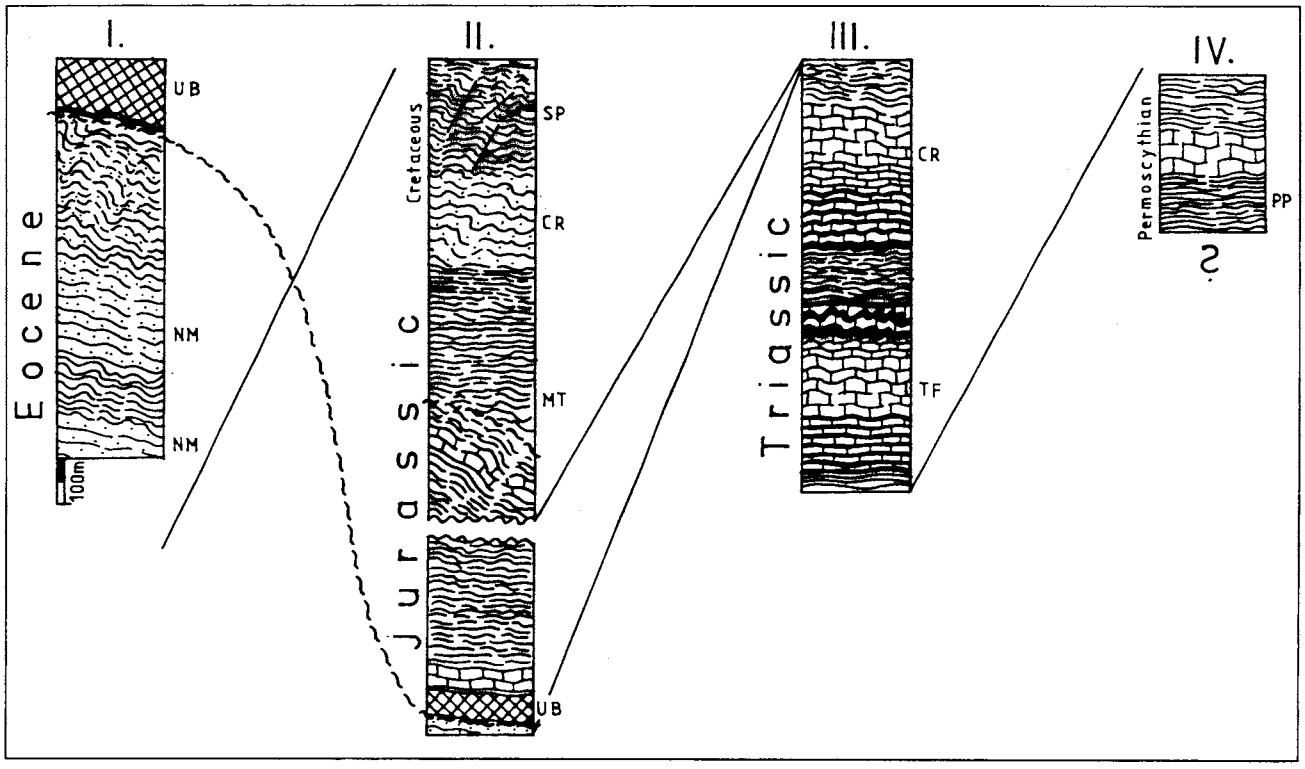


Fig. 2. Lithostratigraphic interpretation of the borehole profiles from the complexes of the Iňačovce-Krichevo unit on Slovak territory.
I. - thin rhythmic-bedded flysch tectonically overthrusted by ultrabasites (UB - ultrabasites, NM - nummulites, wavy line - overthrust plane). **II** - pelitic-aleuritic 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 marbly-limestones and calcphyllites - (Cr - crinoidal detritus, TF - Triassic foraminifers of the genera *Permodiscus-Aulotortus*). **IV** - complex of phyllitic schists, calcschists and marbly limestones (PP - Upper Permian palynomorphs).

Ultrabasic bodies, volcanic rocks and volcanoclastic horizons in the complexes of the Pozdišovce-Iňačovce zone

The presence of ultrabasic rock bodies in the complexes of the Pozdišovce-Iňačovce zone is indicated by extended magnetic anomalies with peaks near Sečovce and Zbudza-Nacina Ves (Mořkovský & Čverčko 1987; Gnojek 1987; Gnojek et al. 1991, etc.). Their presence was also confirmed in five deep boreholes. The ultrabasic rocks include serpentinized peridotites with preserved primary minerals (olivine, clinopyroxene, orthopyroxene, chromspinel), lizardite-chrysotile serpentinites with relict structures, up to strongly altered talc-chlorite-tremolite-carbonate rocks. According to the primary mineral character (olivine Fo90, orthopyroxene, clinopyroxene) these rocks correspond to metaperidotites, generated in the upper mantle and forming lower parts of ideally developed ophiolite complexes (Coleman 1977). On the basis of the character of the alteration (minerals of lizardite-chrysotile group), these rocks can be compared to metaultramafites in the Mesozoic of the Inner Western Carpathians (cf. Hovorka et al. 1985).

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

The scope of ultrabasic and volcano-sedimentary rock occurrences in the complexes of the Pozdišovce-Iňačovce zone has the character of a clear-cut intrusive-effusive record. With ultrabasic and volcanoclastic rock occurrences, the complexes of the Pozdišovce-Iňačovce zone are similar to 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 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 overthrust structures in the complexes of the Pozdišovce-Iňačovce zone, just in ductile ultrabasic rocks there were being founded planes of décollement. Sheet overthrusting with tectonic superposition of the Mesozoic complexes cut off in ultrabasic bodies on the Paleogene formations was confirmed in borehole Pavlovce-1.

Overthrusting of the Central Carpathian units on the Pozdišovce-Iňačovce zone and their unroofing

The complexes of the Pozdišovce-Iňačovce unit are in places superimposed by remnants of sub-Tatric nappes (Guttenstein limestones and dolomites in the tectonic roof of typical formations of the Pozdišovce-Iňačovce zone in the borehole Hrušov-1). This clearly shows that the Pozdišovce-Iňačovce zone takes a lower and that is more external position than sub-Tatric and perhaps Tatric units. The situation here is similar to the Penninic unit overthrusting by Unterostalpine nappes.

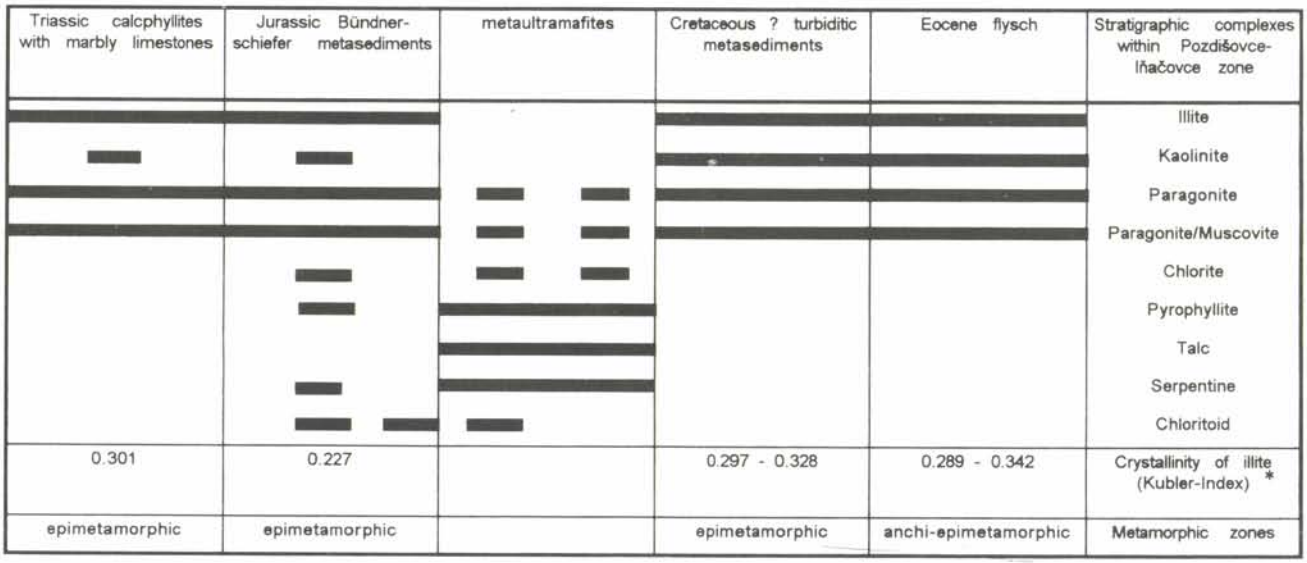
The uncovering of the Pozdišovce-Iňačovce zone was not taking place through erosional cutting off nappe pile, but through tectonic unroofing. Large-scale shear zones trending in Carpathian direction in combination with oblique fault lines formed a conjugate system of a "pull-apart" dome here (cf. Genser & Neubauer 1989, Fig. 3). The unroofing of the Pozdišovce-Iňačovce zone 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 zone, "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).

Structural-deformation effects and Alpine metamorphism in the complexes of the Pozdišovce-Iňačovce zone

The structural-deformation elements observed in the complexes of the Pozdišovce-Iňačovce zone are of planary, linear and fold types. The major structural pattern of these rocks is planes so (pseudo-bedding) showing a clean-cut stretching lineation l1 and silky luster. The planes so are at a small angle cut through by slaty cleavage planes *s1* which are bearers of mineral lineation l2. The most typical phenomenon of deformation of these rocks is a cleavage segmenting and crenulating planary elements *s0* and *s1* (crenulation cleavage). Bending deformation are present in the form of various folds in the complexes of the Pozdišovce-Iňačovce zone. In pelite sequence, intrafolial isoclinal, zig-zag, chevron and rootless folds are dominating. In more competent sandstone 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, etc. The desribed planary, linear, folding and microtectonic phenomena suggest that the complexes of the Pozdišovce-Iňačovce zone underwent a similar structural-deformation development as the formations of the Penninic units. 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 phylosilicates at temperatures under 300 °C (Voll 1980).

Mineral facies (sericite, hydromuscovite-muscovite, quartz, chlorite, chloritoid, pyrophyllite, tourmaline, pyrite, etc.) show that the metamorphic degree in the complexes of the Pozdišovce-Iňačovce zone is low and reflects the conditions from early metagenesis up to epizone. Similar metamorphic conditions are sugested by the results of the determining of illite "crystallinity" (pers. comm. Dr. A. Biroň). The values of Kübler's index, measured in the metapelites of the Pozdišovce-Iňačovce zone, vary within the range of 2.27 - 3.42 which corresponds to metamorphic conditions between anchizone and epizone (3.0 - 3.5 according to Árkai 1983 et al. 1981). On the basis of illite "crystallinity", such a metamorphic influence can be proved with all the lithostratigraphic units of the Pozdišovce-Iňačovce zone, i.e. including Eocene flysch (Tab. 1). The highest metamorphic degree in the complexes of the Pozdišovce-Iňačovce unit is shown by dark schists filled with rosette-like chloritoid aggregates. This mineral is an index mineral of yet-typical greenschist facies (Frey 1987). Metamorphic conditions are possible to be specified on the basis of chloritoid-pyrophillite co-existence, which is stable within temperature range 400 - 500 °C at water pressure 3.5 - 4 kbar (Spear & Chenney 1989).

Table 1: Values of illite "crystallinity" in the complexes of the Pozdišovce-Iňačovce zone.



* Values are influenced by presence of Paragonite and Paragonite/Muscovite

General conclusions

The Iňačovce-Krichevo unit, building a major part of the Transcarpathian Depression basement, is formed by Penninic-type complexes:

- There are monotonous sequences of fine turbiditic sediments of Bündnerschiefer type with ultrabasic bodies, volcanic rocks and volcanoclastic horizons, and thin rhythmic-bedded Upper Cretaceous? and Eocene flysch;
- The Iňačovce-Krichevo unit has an overthrust structure combined with shearing; the Permo-Mesozoic up to Eocene sediments participate in it. Its rock complexes were anchizonally/epizonally metamorphosed, considerably overfolded and stretched during post-Eocene tectonogenesis;
- In the Western Carpathian structural plan the paleotectonic element of the Iňačovce-Krichevo unit responds to hypothetical Vahicum (= unspecified Penninicum). Lithological filling (Bündnerschiefer formations), Neoalpine character of the deformation and metamorphizm and extra-Tatric position of the Pozdišovce-Iňačovce unit rather support its North Penninic origin. In this context Brianconnais affinity of the Tatricum (Debelmas 1960; Tollman 1975) and location of the Southern Penninicum into more internal zones of the Eoalpine colission have again become topics for discussion (Soták & Tomek in prep.).

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 (Maheľ 1983; Plašienka et al. 1991) and behind the Hornád fault. Tectonic unroofing of the Penninic sequences in the the East Slovakian Basin area was a result of a strong extension on the conjugate sytem of shear zones and fault lines. Like in the Penninic windows of the Alps, there was exhumed s "pull-apart" dome here with the most distinct crustal thinning and highest thermal gradient in the Western Carpathians (see Fusán 1985; Pospíšil & Bodoky 1981; Čermák 1979). "Pull-apart" processes also controlled the opening of the basin itself during molasse 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 (Maheľ 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).

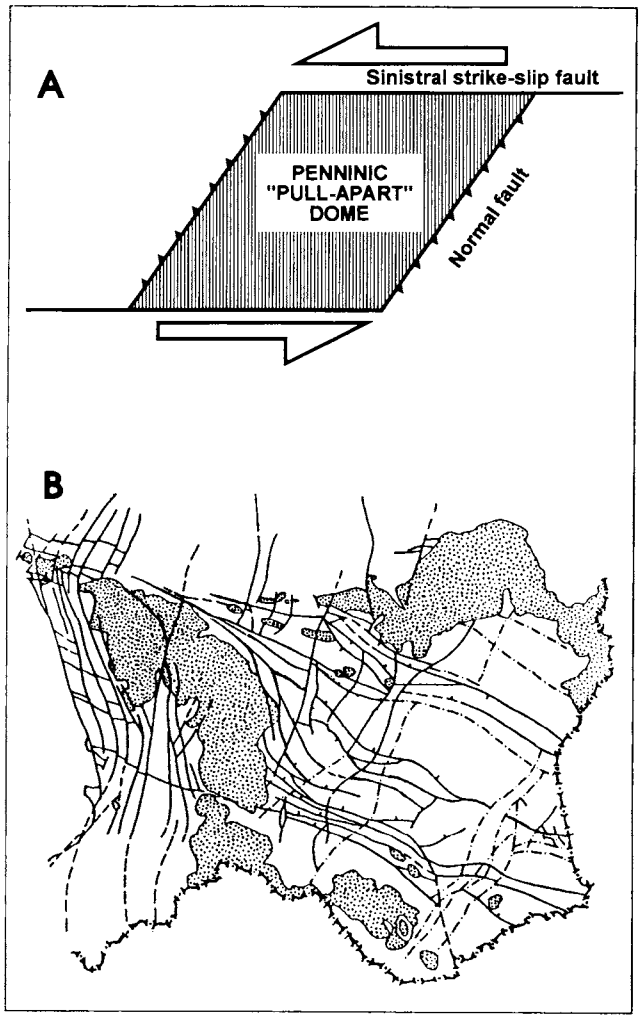


Fig. 3. Configuration of structural elements of the East Slovakian Basin related to "pull-apart" dome model.
A - "Pull-apart" dome model for the Penninic windows according to Genser & Neubauer (1989).
B - "En echelon" style of the East Slovakian Basin with NW-SE trending strike-slip components and conjugate fault system (taken from Čverčko 1977; Vass et al. 1988).

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