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

JÁN MELLO[1], PETER REICHWALDER[2] & ANNA VOZÁROVÁ[3]

[1]Geological Survey of Slovak Republic, Mlynská dolina, 1, 817 04 Bratislava, Slovakia
[2]Dept. of Geology and Palaeontology, Faculty of Science, Comenius University, Mlynská dolina, G 842 12, Bratislava, Slovakia
[3]Dept. of Mineralogy and Petrology, Faculty of Science, Comenius University, Mlynská dolina, G 842 12 Bratislava, Slovakia

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

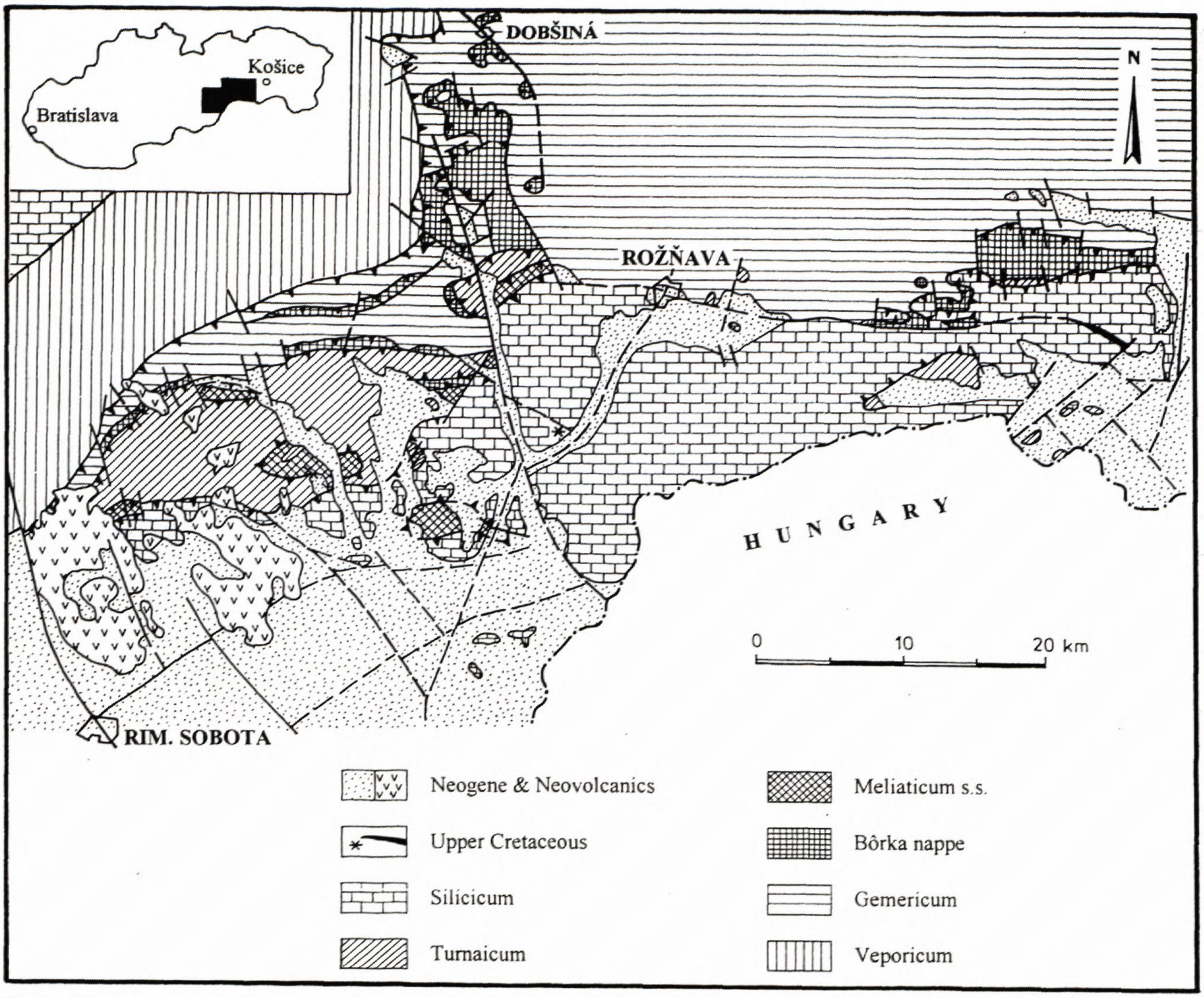


Fig. 1: Extension of the Bôrka Nappe in the northern part of the Slovak Karst and in the southeastern part of the Slovenské Rudohorie Mts.

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

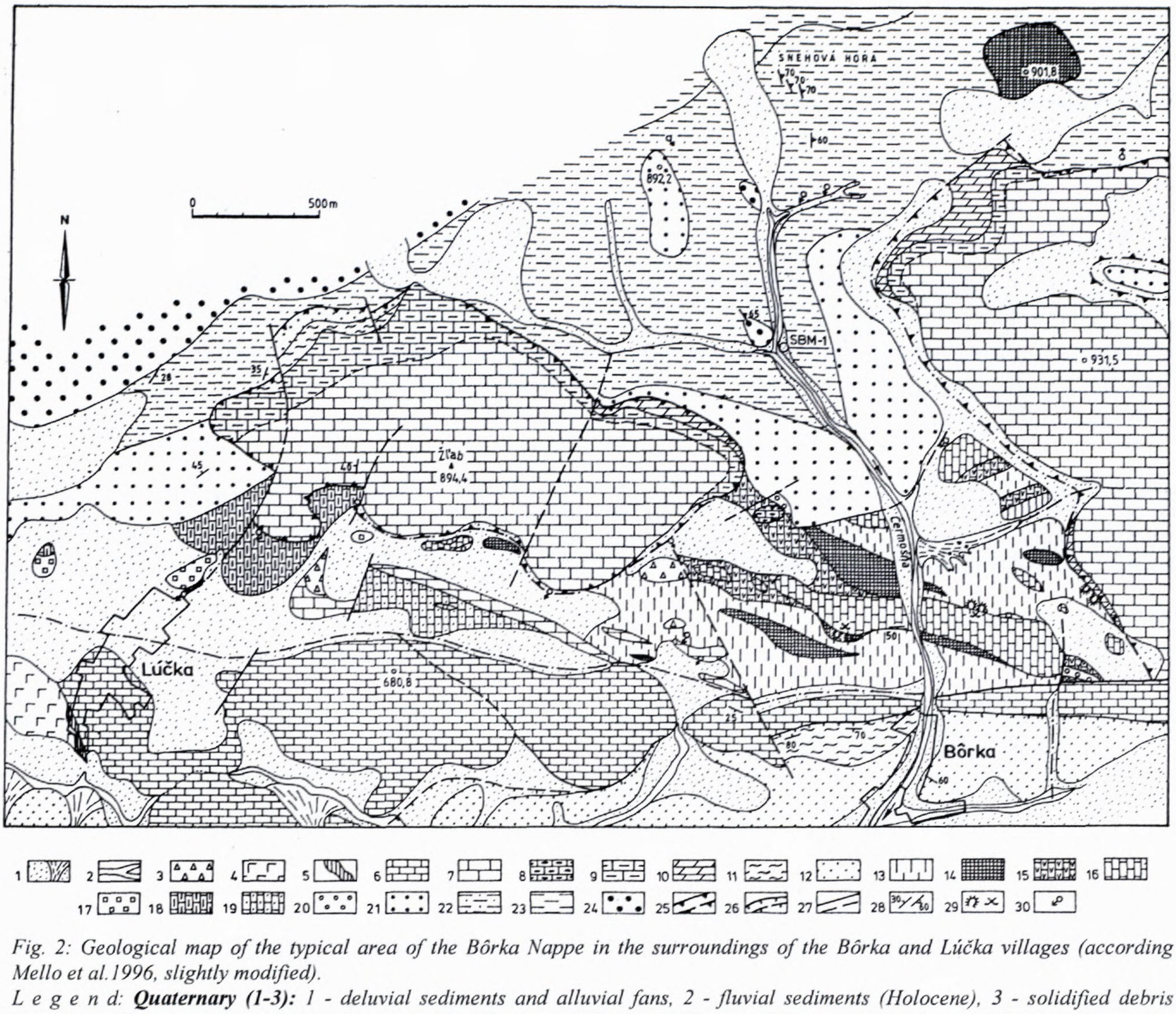


Fig. 2: Geological map of the typical area of the Bôrka Nappe in the surroundings of the Bôrka and Lúčka villages (according Mello et al.1996, slightly modified).

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

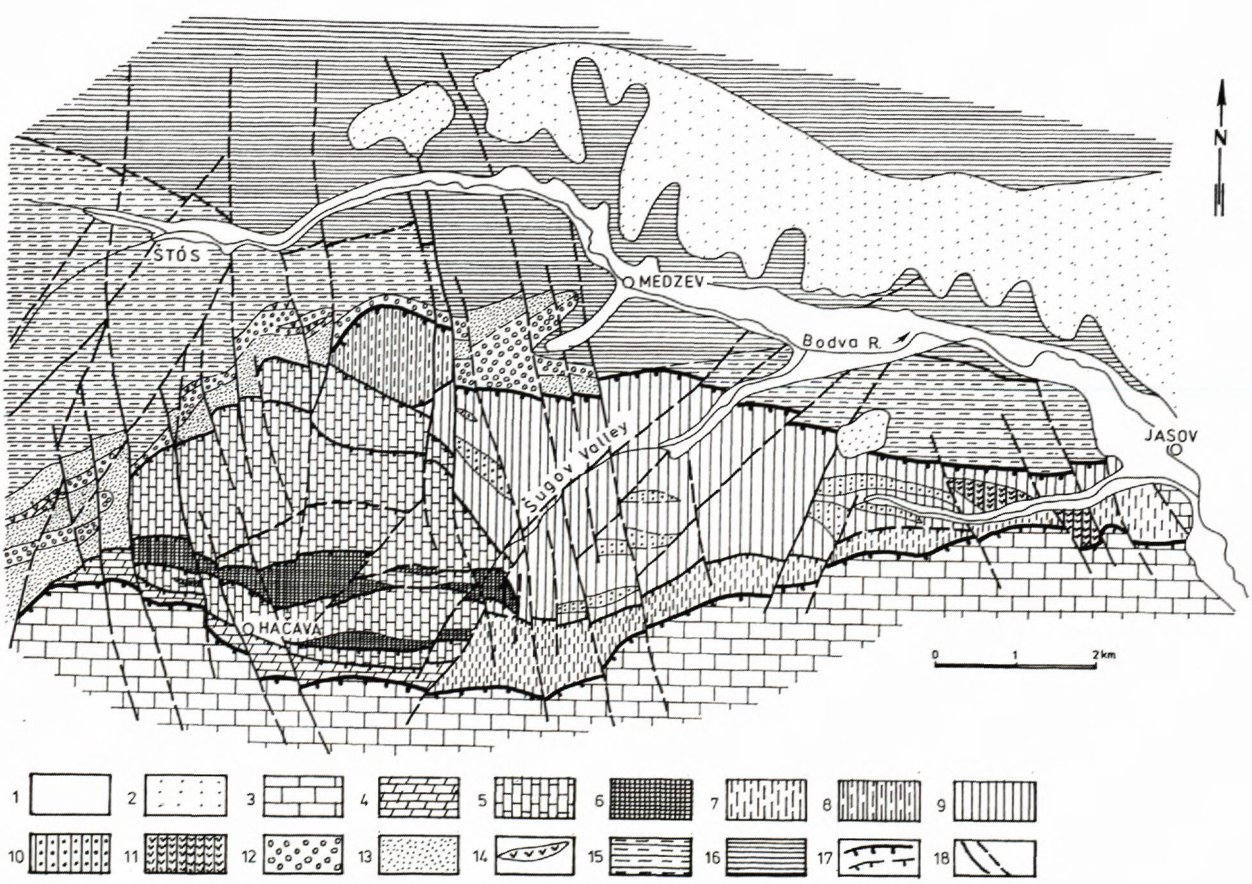


Fig. 4: Simplified geological map of the Bôrka Nappe between Hačava and Jasov (after Reichwalder in Mello et al. 1996).
1. Quaternary deposits undivided, 2. Neogene deposits undivided; ***3. Silica Nappe*** *(Triassic - Jurassic);* ***4. Turňa Nappe*** *(Triassic);* ***Bôrka Nappe (5-11):*** *5. dolomites, 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

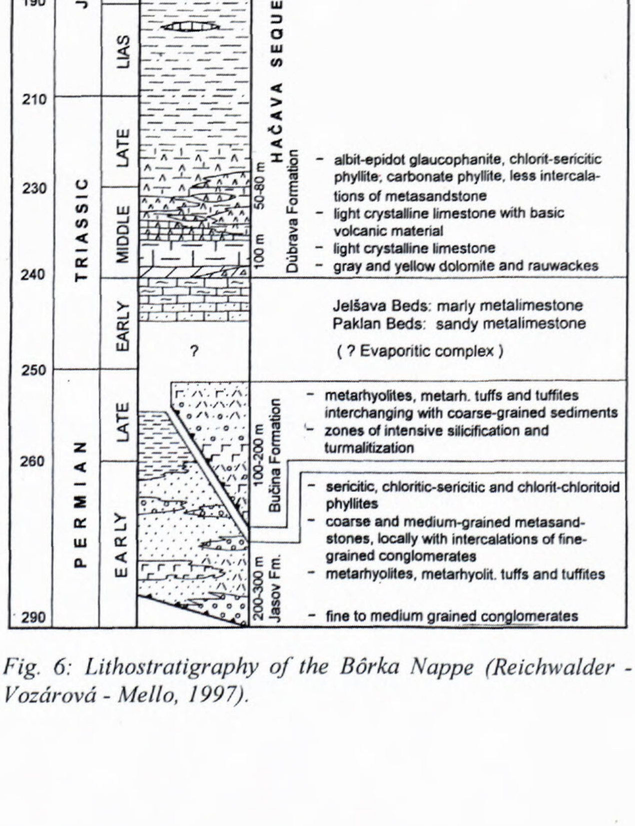


Fig. 6: Lithostratigraphy of the Bôrka Nappe (Reichwalder - Vozárová - Mello, 1997).

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-

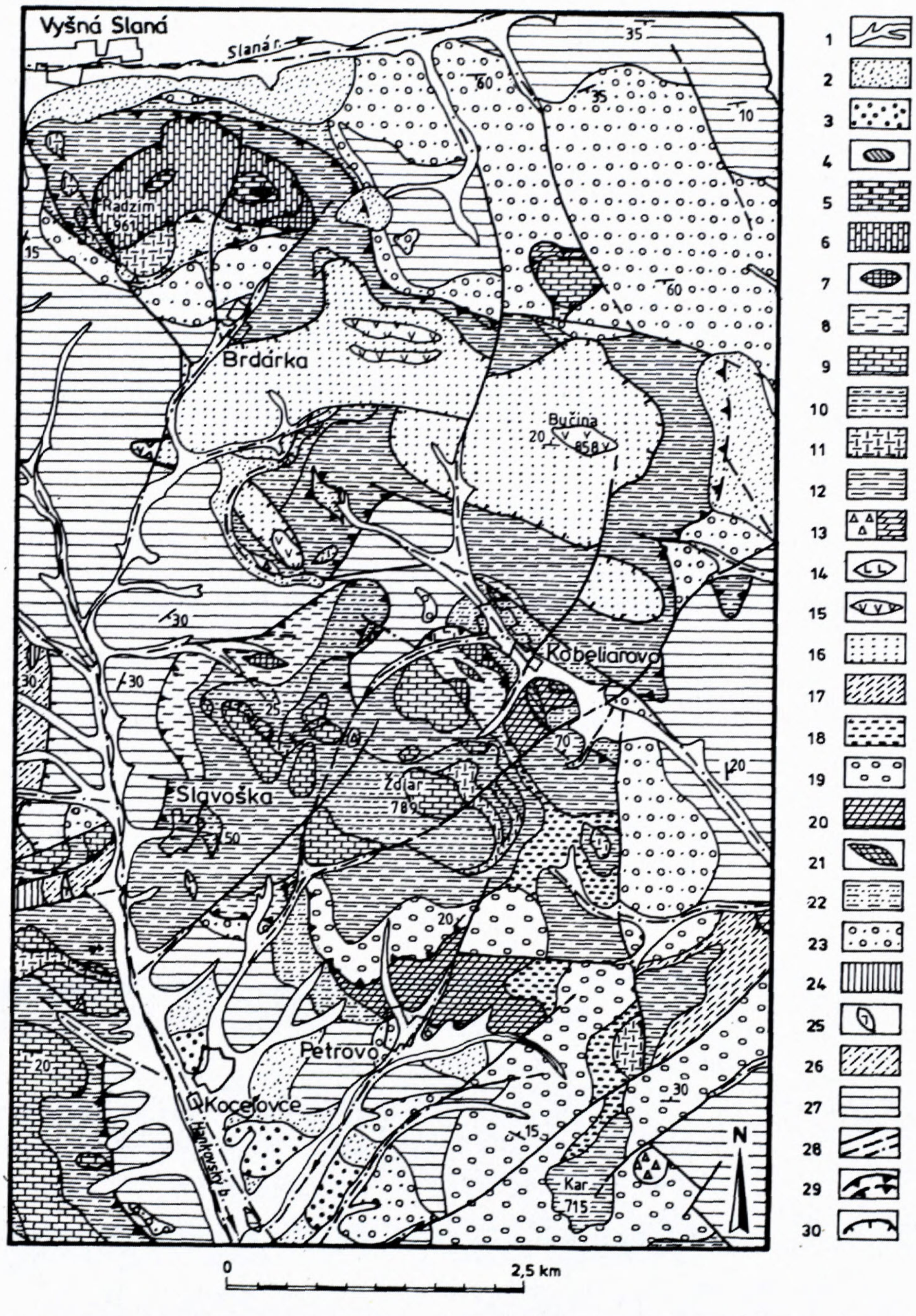


Fig. 8: Geological map of the Bôrka Nappe in the Nižná Slaná Depression (after Mello and Vozár [Paleozoic formations] in Madarás et al.,1995).

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

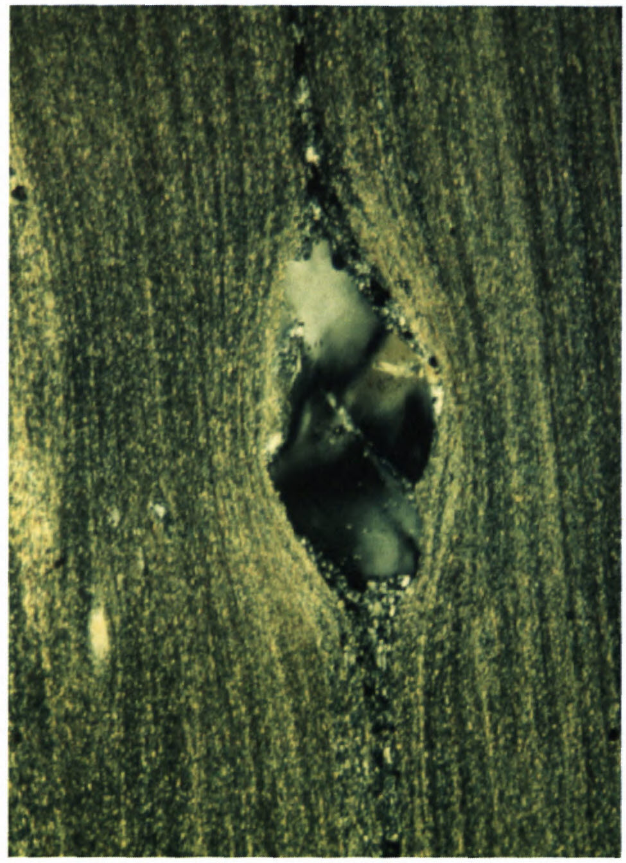
The Bôrka Nappe bears traces of deformation and metamorphism in condition of high pressure and low temperature, i.e. the nappe or at least its parts, had to occur in relatively deeper parts of subduction zone for a certain period. Basically, it is a remnant of a subduction-accretionary complex containing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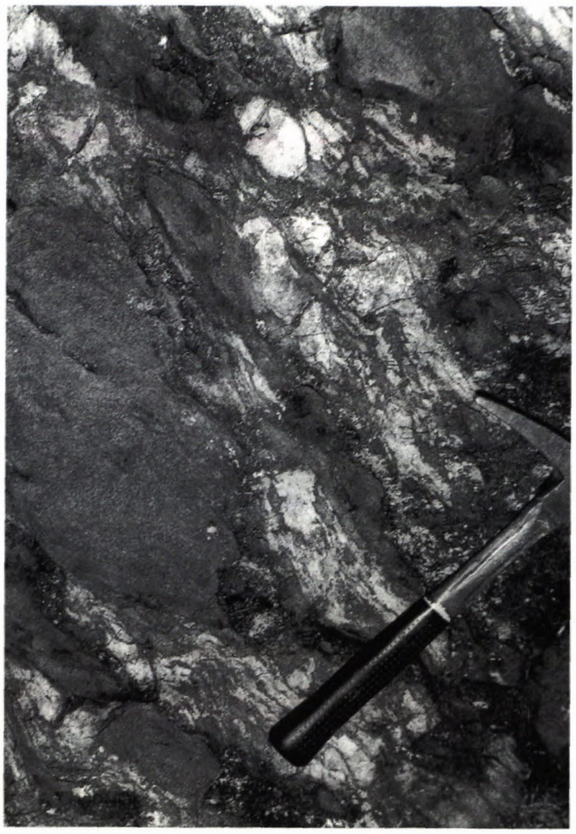
PLATE I

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.



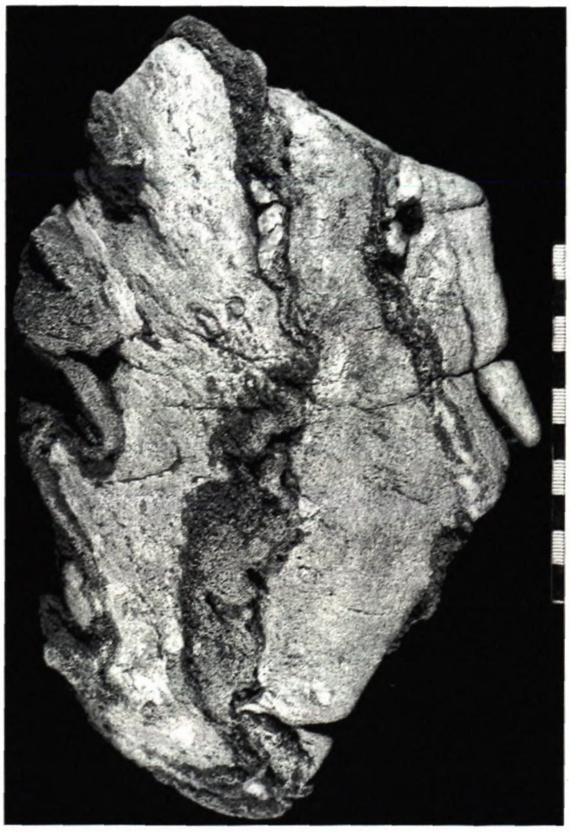


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PLATE II

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.