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Commission on Metamorphism

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Excursion Guide

Metamorphic evolution of the eastern part of the Western Carpathians, with emphasis on Meliata Unit

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Preface

The Inner to Central parts of the Western Carpathians consist of several tectonic units that provide unique opportunity to investigate Alpine and Pre-Alpine tectonothermal evolution in the Western Carpathians. Lithological and geochemical compositions of sedimentary and igneous rocks indicate the presence of Alpine-Meliata and Pre-Alpine Rakovec suture zones. The Meliata blueschists are the only evidence of subducted Triassic Meliata-Hallstatt oceanic basin and adjacent continental wedge, which occurred during the Jurassic time. These processes were followed by the Cretaceous collision that suffered not only the Gemer but also the Vepor Belts. Since Alpine and Variscan metamorphism occurred in most tectonic units under similar pressure and/or temperature conditions, for reconstruction of Alpine development is necessary to understand Pre-Alpine history of each tectonic unit.

The Field Meeting is aimed to comprehend Alpine and Pre-Alpine tectonothermal evolution in the eastern parts of the Western Carpathians with a special respect to subduction and exhumation history of the Jurassic Meliata blueschists, as well as of Cretaceous collision in the Western Carpathians. In order to clear metamorphic characteristic and geological position of each unit a brief outline on structure and metamorphism of the Central Western Carpathians is given in the excursion guide.

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Contents

1. OUTLINE ON STRUCTURE AND METAMORPHISM OF THE WESTERN CARPATHIANS

The Western Carpathian Variscan belt, supposed as prolongation of the southern branch of the European Variscides (e.g. Matte, 1986), was migrated due to Alpine tectonometamorphic processes to the northeast (Mahel', 1986; Plašienka, 1991). This migration is documented by asynchronous occurrence of two oceanic domains (the Triassic-Jurassic Meliata and the Jurassic-Cretaceous Pieniny), which bounded the Central Western Carpathians. The Meliata and Pieniny oceanic basins are assumed to disappear by Middle Jurassic subductions. High-pressure low-temperature rocks, indicating subduction of oceanic and continental rocks occur along the Meliata tectonic unit, situated in the southern part of the Central Western Carpathians (southern from the Gemericum) and in the Pieniny Klippen Belt (Fig. 1).

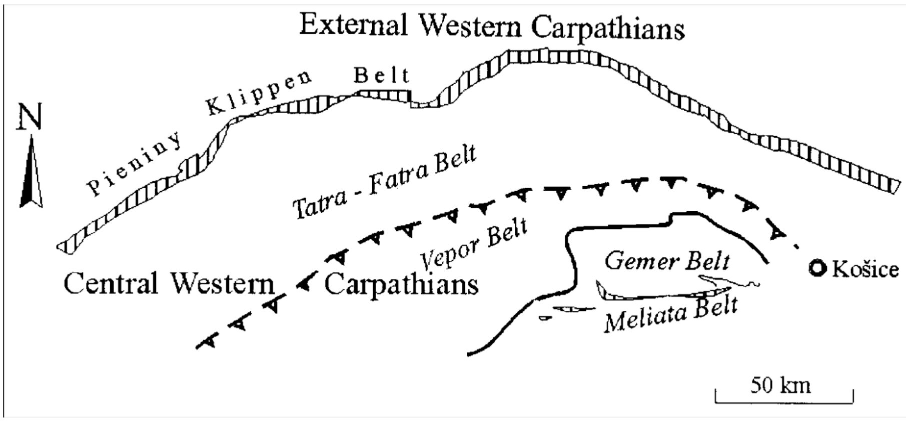

Fig.1. Tectonic sketch of the Western Carpathians.

The Western Carpathians are transversally subdivided into *External, Central and Internal Western Carpathians* (Fig. 1, 2). The External Western Carpathians, which are separated from the Central Western Carpathians by the *Pieniny Klippen Belt,* comprise molassic sediments of the Tertiary Carpathian Foredeep, deposited on the margins of the North European Plate in Moravian and southern Poland and the large Tertiary accretionary wedge of the Flysch Belt, divided into the outer Silesian - Krosno and the Inner Magura Belt. The prominent Alpine crustal-scale units of the Central Western Carpathians from N to S are the Tatric, Veporic and Gemeric units (Fig.2) topped by several superficial nappes (i.e. Fatricum, Hronicum and Silicicum). The crustal units comprise pre-Alpine amphibolite to greenschist facies basement, Variscan (Devonian-Permian) granitoids (Fig.3) and their Late-Paleozoic and Mesozoic sedimentary cover sequences.

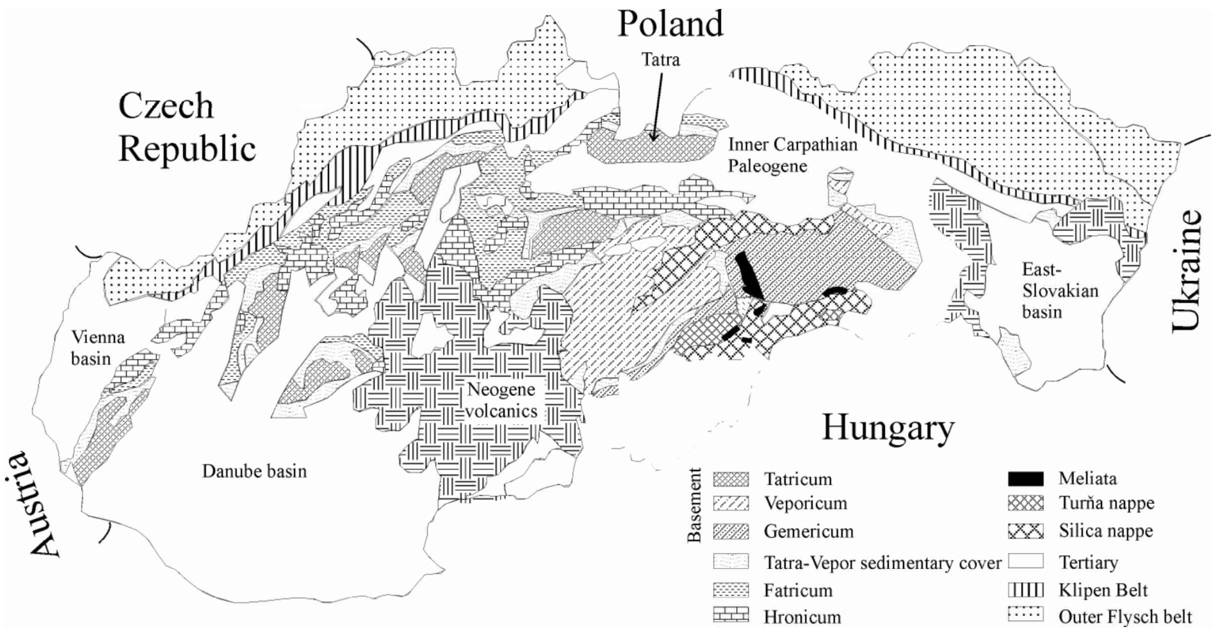

Fig.2. Schematized geological map of the Western Carpathians (Geologica Survay of Slovak Republic, 1996).

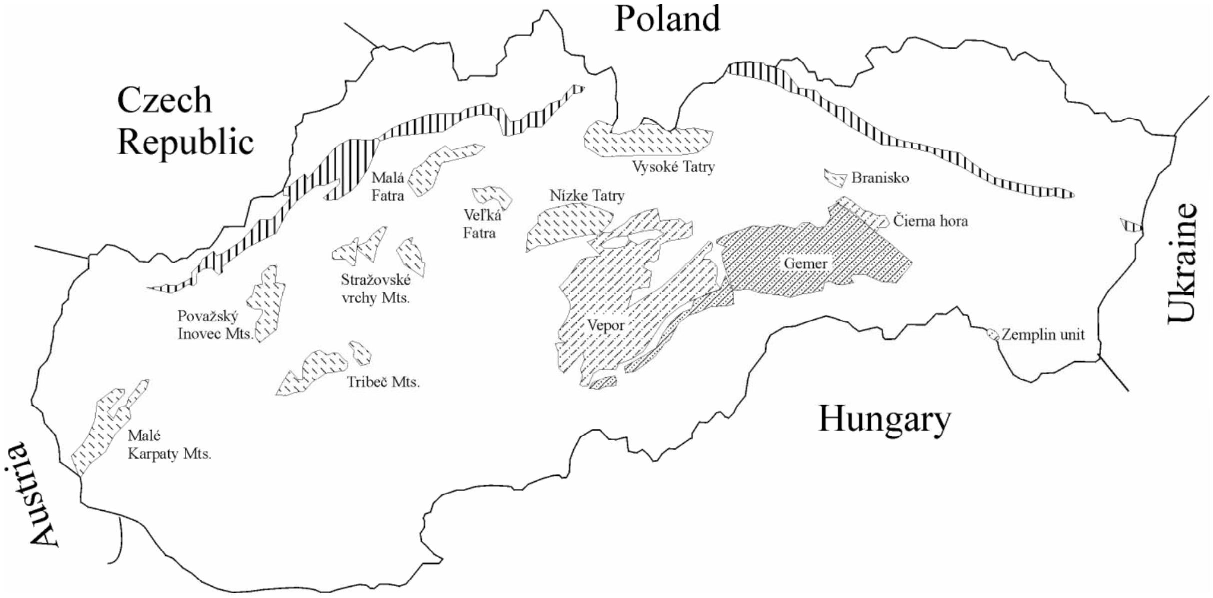

Fig.3. Pre-Alpine basement rocks exposed in the Tatra, Vepor and Gemer Belts.

1.1. External Western Carpathians

The External Western Carpathians comprise late Tertiary molassic and Jurassic - lower Miocene flysch sediments, covering the margins of the North European Plate in the southern part of Poland and in Moravia. The Flysch Belt consists of several thrust units grouped into the Silesian and Magura nappes. With respect to pebbles in some Tertiary flysch conglomerates in Moravia, the composition of their source was similar to the basement of the Brunovistulic terrane consolidated during the Cadomian orogeny (Dudek, 1980).

1.2. Central Western Carpathians

Following Plašienka et al. (1997), the Central Western Carpathians are subdivided into four different zones: *the Pieniny Klippen Belt, the Tatra-Fatra Belt of core mountains, the Vepor Belt and the Gemer Belt.* The latter is partly overthrusted by slices and nappes of the Inner Western Carpathians units (Silica nappe, Turňa nappe and Meliata unit).

1.2.1. Pieniny Klippen Belt

The Pieniny Klippen Belt (Fig. 1, 2) is an extremely shortened tectonic unit of the outer zones of the Western Carpathians, starting near Vienna and reaching in some places a width of 22 km. In the Carpathian arc, it attains a length of 800 km. The only evidence of subduction of ancient oceanic crust are pebbles of blueschist facies rocks in Albian conglomerates near Považská Bystrica (Šímová, 1982) and in Cretaceous Krížna nappe at Humenné (Ivan and Sýkora, 1993). The source of the clastic materials was a hypothetical Pieninic exotic ridge that is supposed to have been located south of the sedimentary basin (Marschalko, 1986, Mišík, 1997). Following Plašienka (1995), the pebbles could came from the Meliata unit. A Middle Jurassic ^{40}Ar-^{39}Ar age (155.4 Ma) of blueschist metamorphism has been recently obtained by Dal Piaz et al. (1995) on two glaucophane concentrates from metabasite pebbles in the Klippen Belt.

The high-pressure rocks comprise three different types ranging from pumpellyite- through lawsonite- to omphacite-bearing blueschists (Fig. 4). In addition to blue amphiboles (glaucophane, ferroglaucophane and winchite), the blueschist pebbles also contain minor amounts of phengite, chlorite, albite and quartz. The jadeite component in omphacite ranges from 38 to 60 mol percents. Si contents of phengite are 3.45-3.5 atoms per formula unit based on 11 anhydrous oxygens. The estimated temperatures and pressures are 310-360 °C at 7-9 kbar for pumpellyite-, 325-375 °C at 9-11 kbar for lawsonite- and 360-420 °C at 10-12 kbar (Faryad and Schreyer, 1997) for the omphacite-bearing blueschists. These PT conditions indicate a subduction regime of pre-Albian age formerly located probably in a relatively external portion of the Western Carpathians with a mean linear geotherm of about 9-10 °C/km.

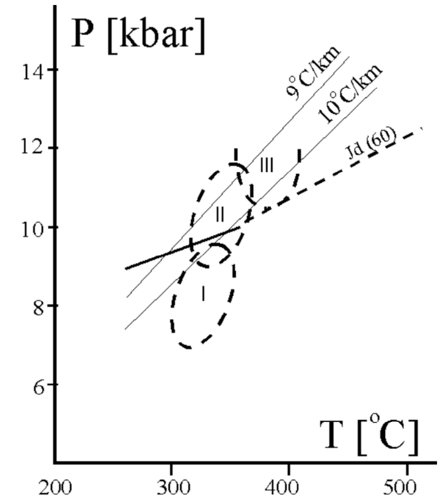

Fig. 4. P-T conditions of blueschists occurring as pebbles in the Albian conglomerates from the Klippen (Faryad and Shreyer, 1997):
I. pumpellyite-glaucophane/winchite,
II. pumpellyite-lawsonite-glaucophane
III. omphacite-lawsonite- glaucophane.

1.2.2. The Tatra-Fatra Belt

The Tatricum and Veporicum are extensive thick-skinned crustal sheets composed of pre-Alpine (generally Variscan) basement and its Mesozoic sedimentary cover (Fig. 3). The basement rocks underwent amphibolite to greenschist facies metamorphism. The amphibolite facies metamorphism of the Tatricum and Veporicum had medium- (Pre- or Early Variscan) to low-pressure (Variscan) character (Krist et al., 1992). Following Putiš et al. (1992), Janák et al., (1993) and Bezák et al. (1995) two or three (Lower/Middle and Upper) Variscan lithotectonic units, different in metamorphic conditions, are distinguished in the Central Western Carpathian basement. The Upper lithotectonic unit is mostly represented by high-grade and the Lower unit by medium- to low-grade rocks (Fig. 5).

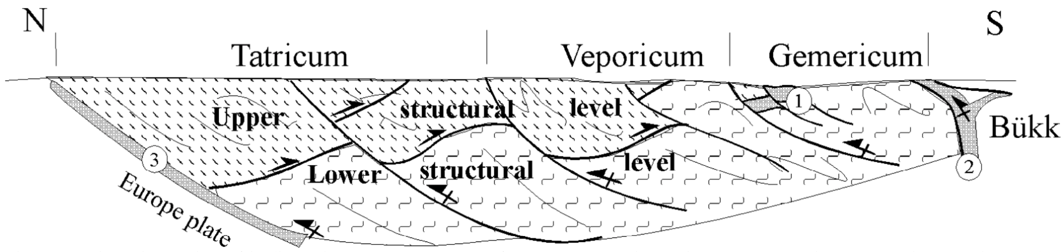

Fig. 5. Schematized geological profile (based on interpretation of Putiš, 1992, Plašienka, 1992, Bezák, 1994 and Faryad, 1997) indicating Variscan Upper and Lower lithotectonic units with different metamorphic conditions and Alpine structures. Numbers: 1 and 2 represent Variscan and Alpine suture zones, respectively

1.2.2.1. Pre-Alpine metamorphism in the Tatra-Fatra Belt

The Tatric basement consists of early Paleozoic volcanosedimentary complexes (mostly paragneisis, mica-schist, phyllites and amphibolites) and several varieties of Variscan granitoids. The basement rocks are exposed in 9 massifs from SW to NE in the Malé Karpaty, Považský Inovec, Tribeč, Stražovské Vrchy (Suchý, Malá Magura, Žiar), Malá Fatra, Veľká Fatra, Nízke Tatry and in Vysoké Tatry (Fig. 3).

The Malé Karpaty Mts. basement rocks underwent Pre-Alpine greenschist to amphibolite facies metamorphism, which was partly followed by thermal overprint of granite magmatism. Metamorphic minerals in metasediments are biotite, muscovite, garnet, staurolite, plagioclase and sillimanite. At contacts with granites also andalusite and cordierite occur (Korikovskij et al., 1984). Metamorphic conditions of ca 550 °C and 3-4 kbar were estimated for regional and 650 °C at 2 kbar for contact metamorphism (Fig. 6). Recently Dyda (1997) estimated pressure of 6 kbar for the Malé Karpaty basement rocks. Geochronological data, based on Rb-Sr isochrone gave 320-350 Ma age for granitoid formation (Cambel et al., 1980).

The Považský Inovec Mts. are characterized by the presence of metasedimentary rocks with lenses and layers of metabasites and synkinematic granitoids. In contrast to the Malé Karpaty Mts., metamorphic mineral assemblages in metasediments from Považský Inovec Mts. indicate relatively higher P-T conditions. They are characterized by the presence of sillimanite and kyanite, associated with garnet, biotite, muscovite, partly also with staurolite (Korikovskij and Putiš, 1986). Andalusite have been also found (Krist et al., 1992). Lower pressures of 4-5 kbar at 600 °C were estimated using petrogenetic grids, however higher pressures of 7-10.5 kbar (Fig. 6) were obtained using plagioclase-garnet barometry.

The Tribeč Mts. is formed by granitoids and gneisses with amphibolites. Paragneisses contain biotite, white mica, plagioclase, K-feldspar and garnet (Krist et al., 1992). Metabasites mostly consist of amphibole and plagioclase. However, some garnet and clinopyroxene-bearing rocks may indicate the relics of eclogites (Hovorka and Méres, 1990; Janák et al., 1997).

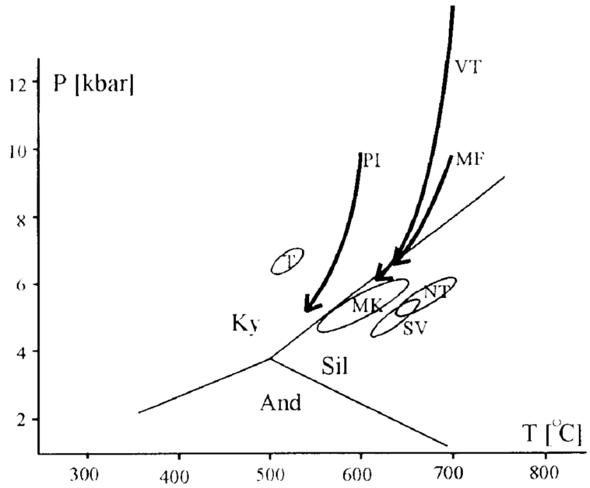

Fig. 6. Summarized P-T data for Variscan metamorphism in the Tatra basement (see text for references):
MF-Malá Fatra
MK-Malé Karpaty
NT-Nízke Tatry
PI-Pvažský Inovec
SV-Stražovské Vrchy
T-Tribeč
VT-Vysoké Tatry

The most common rocks in the **Stražovské vrchy Mts.** are paragneisses and that associate with small amounts of graphite schists and amphibolites (Maheľ, 1986). Besides biotite, muscovite and plagioclase, paragneisses contain garnet, staurolite, sillimanite, andalusite and cordierite. Metamorphic conditions of 600 °C at 3- 4 kbar are estimated by Krist et al (1992), however relatively higher pressure 5.5 kbar at 680 °C were inferred by Dyda (1990). ^{207}Pb-^{206}Pb and Ar-Ar data from zircone and amphibole respectively, gave 356-371 Ma age for granitoid magmatism in the Stražovské Vrchy Mts. (Kráľ et al., 1997).

Pre-Alpine metamorphic rocks of the **Malá Fatra Mts.** occur in the most nortwest segment of the Tatric basement. They are represented by migmatites, paragneisses with small amounts of orthogneisses and amphibolites. Metamorphic minerals in paragneisses are biotite, white mica, garnet, sillimanite, plagioclase, K-feldspar (Kamenický, 1956). Besides amphibole and plagioclase, some amphibolites contain also garnet and diopside. Metamorphic conditions, estimated for the Malá Fatra Mts. range from 630 °C /5.5 kbar to 750 °C /7.5 kbar (Krist et al., 1992). Some garnets from gneisses, indicating high-temperature, are assumed to be relics of Cadomian granulite facies metamorphism (Hovorka et al., 1987). Besides amphibole and plagioclase, metabasites may contain also garnet and clinopyroxene (Hovorka et al., 1992), for that Janák et al. (1997) estimated pressure of 0.8-1.0 GP at 700 °C.

The **Veľká Fatra Mts.** are characterized by the presence of granites, migmatized gneisses with small amount of amphibolites. The gneisses contain one or more of the minerals biotite, garnet, sillimanite and staurolite (Korikovský, 1987). ^{40}Ar-^{39}Ar data from micas gave 338 Ma granitoid magmatism (Kohút et al., 1998)

The **Nízke Tatry Mts**. consist mostly of granites that are enveloped by migmatites, orthogneisses and paragneisses that partly contain layers of amphibolites. Micaschists and phyllites are also described from several localities. The gneisses are characterized by the presence of white mica, biotite, plagioclase, K-feldspar, rarely also sillimanite, garnet and cordierite. Metamorphic conditions of 600-700 °C and 4-5 kbar are assumed for gneisses (Pitoňák, 1985, Krist et al., 1992) and 450 °C for phyllites (Molák et al., 1988). Amphibolites with garnet and clinopyroxene were also described from this area (Spišiak and Pitoňák, 1989). Rb-Sr data indicated 362 Ma cooling age for granitic rocks (Cambel et al.,1990)

The **Tatra Mts.** crystalline basement is composed of pre-Mesozoic metamorphic rocks and granites, overlain by Mesozoic and Cenozoic sedimentary cover sequences and nappes. Metamorphic rocks are abundant in the western part (the Western Tatra Mts.), whereas in the eastern part (the High Tatra Mts.) they form only xenoliths in granites. Within the basement, two superimposed tectonic units – lower and upper, differing in lithology and metamorphic grade, have been distinguished (Janák, 1994). These units are separated by a Variscan thrust fault – a major tectonic discontinuity in the crystalline basement of the Tatra Mountains.

The lower unit is composed of medium-grade micaschists. Kyanite-, staurolite-, fibrolitic sillimanite- and garnet-bearing metapelites alternate with quartz-rich metapsammites, indicating former flysch sediments. The staurolite-kyanite and kyanite-sillimanite (fibrolite) zones are separated by the staurolite-out isograd. Metamorphic conditions in the lower unit micaschists reached 570-640°C and a pressure of 6-7 kbar (Janák, 1994).

The upper unit is composed of high-grade metamorphic rocks and granites. High-pressure metamorphic rocks occur at the base of the upper unit (kyanite zone). The amphibolites are banded, with layers of mafic (amphibolite) and felsic (tonalitic to trondhjemitic) composition.. They enclose lenses of eclogitic relics with garnet and clinopyroxene. Estimated PT conditions of high-pressure (eclogite) stage are 700-750°C at minimum pressure of 15-16 kbar (Janák et al., 1996). Metapelites with kyanite show migmatisation and formation of granite leucosomes due to dehydration melting of muscovite at more than 700°C and 11-12 kbar (Janák et al., 1999). Orthogneisses are mylonitic with augen-like porphyroclasts of K-feldspar. Single zircon grain age determinations (Poller et al., 1997) indicate partial melting and crystallization of granitic orthogneiss precursor in Early Devonian (ca. 405 Ma). Higher levels of the upper unit (sillimanite zone) are intruded by a sheet-like granite pluton. In the metapelites, migmatisation is ubiquitous and prismatic sillimanite together with garnet, K-feldspar and cordierite are diagnostic minerals. Dehydration melting of biotite at more than 750-800 °C and 8-10 kbar produced garnet-bearing leucosomes. Nearly isothermal decompression to ca.4 kbar resulted in the cordierite formation (Janák et al., 1999). Amphibolites contain garnet, but eclogitic relics are not preserved. The migmatites and some granitoids from the Western Tatra are Late-Devonian to Early Carboniferous (ca.370-340 Ma), whereas the diorites and granites from the High Tatra are Late Carboniferous (ca. 340-310 Ma), according to zircon single grain dating (Todt. et al., 1998; Poller et al., 1999).

Inverted metamorphic zonation in the Tatra Mts. is related to Variscan top-to-the-south, southeast thrusting and west-east (orogen-parallel) extension (Fritz et al., 1992; Janák, 1994; Janák et al., 1999). ^{40}Ar-^{39}Ar cooling ages of micas from granites and sillimanite zone migmatites are in the range 330-300 Ma (Maluski et al., 1993; Janák, 1994), recording relatively rapid exhumation and decompression of the thermally weakened lower crustal root, during the collapse of Variscan orogen. Present data indicate a polystage tectonothermal evolution of the Tatra Mts. during Variscan orogeny and only weak Alpine overprint.

1.2.2.2 Alpine metamorphism in the Tatra-Fatra Belt

The sedimentary cover of the Tatricum is represented by varied lithologies, mostly carbonate, sandstones and shalles of Permian-Cretaceous ages (Plašienka, 1995). The Fatricum (Krížna nappe) is a system of detached sedimentary nappes overlying the Tatric cover. The late Scythian shales and evaporites represent the main décollement horizon. The cover sequences of the Veporicum unit is approximately the same as in the Tatricum unit, but Cretaceus and Jurassic formations are completely missing in some zones. The Hronicum (Choč nappe) is a large cover nappe system overlying the Fatricum and consists of Upper Carboniferous (Vozárová and Vozár, 1988) to Cretaceous sediments. Besides Upper Carboniferous dioritic dykes, the late Paleozoic igneous activity is represented by Permian tholeitic basalts of continental affinity (Vozár, 1997).

Alpine metamorphic overprint in the Tatra-Fatra Belt basement units can be estimated by new-formed minerals in Variscan granitoid rocks that mostly indicated ca 330 Ma cooling age. The granitoid magmatism closed Variscan metamorphic cycle that occurred in greenschist to amphibolite facies conditions in the Central Western Carpathians. The second most important criteria for investigation of Alpine metamorphism are metamorphic minerals in the Upper Carboniferous, Permian to Mesozoic cover sequences. Petrological investigation of both granitoid and cover rocks indicated very low-grade metamorphic conditions corresponding to anichzone (Krist et al., 1992). Recently Korikovsky et al (1997) studied Permo-Mesozoic cover rocks in the Malé Karpaty Mts. and based on illite-crystalinity data and composition of potassium white-mica they assumed metamorphic temperature of 250-300 °C. Relatively higher temperatures of 270-300 °C (Fig. 7) were inferred for the Považský Inovec and Tribec Mts. where metapelites and metapsammites may contains white mica, chlorite, albite, paragonite and K-feldspar (Korikovskij et al., 1997). Metabasites are characterized by the presence of chlorite, calcite, epidote and albite.

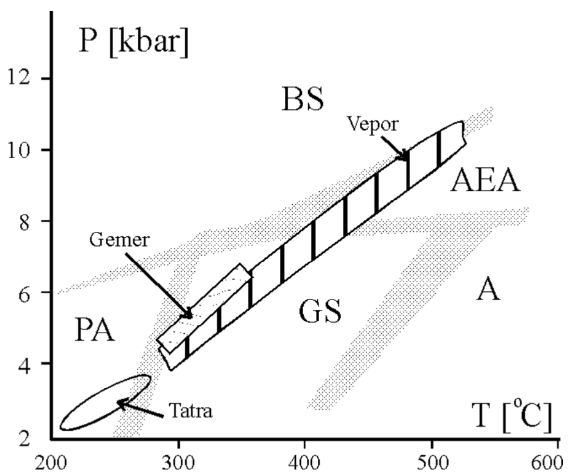

Fig. 7. Summary of P-T conditions of Alpine metamor-phism in Tatra-Vepor and Gemer Belts (see text for references).
PA - Pumpellyite-actinolite facies
GS - Greenschist facies
A - Amphibolite facies
AEA - Albite-epidote-amphibolite facies
ES - Blueschist facies
E - Eclogite facies

1.2.3. The Vepor Belt

The Vepor belt comprises eastern part of the Nízke Tatry Mts., western part of Slovenské Rudohorie Mts., Branisko and Čierna Hora Mts. (Fig. 3). Position of the Zemplín unit, situated in the most eastern part of the Western Carpathians is interpreted differently (for more comperhensive discussion see below). The Vepor Belt consists of basement/cover thick-skinned sheet, superficial nappes of the Silicicum and late Cretaceous-Tertiary cover rocks.

1.2.3.1 Pre-Alpine metamorphism in the Vepor belt

The Veporic unit is a wedge-like, southward-thickened body rooted in the lower crust, where it juxtaposes the Meliata suture (Tomek, 1993; Vozár et al., 1996). The Veporic unit overrides the Tatric-Fatric basement/cover sheet in the north-west (Biely and Fusán, 1967, Plašienka, 1991). From the south-east, it is overthrust by the Gemeric thick-skinned imbricated stack, overlain by the Meliatic oceanic accretionary-suture complexes and the Silicic cover nappes. The exposed eastern part of the Veporic unit in inner zones of the Central Western Carpathians of Slovakia (the rest is covered by Tertiary sediments and volcanics, see Fig. 2) displays an elliptical domal structure, with an onion-like arrangement of the Variscan basement and Permian–Mesozoic cover complexes.

The Veporic basement is composed of various metamorphic and igneous rocks, partly preserving the Variscan nappe structure (Bezák, 1994; Putiš, 1994). The lower structural complex consists of micaschists and gneisses, the upper unit contains gneisses, migmatites and amphibolites intruded by the Vepor granitoid pluton of Variscan age. From northwest to southeast eleven complexes have been distinguished: Ľubietová, Hron, Janov Grúň, Kraľova Hoľa, Muráň gneisses, Ostrá, Klenovec, Hladomorná Dolina, Sinec, Lovinobaňa and Predná Hoľa (Fig. 8).

The position of probably Upper Paleozoic metasedimentary and metavolcanic rocks, occurring in several places in central parts of the dome, is not quite clear in this scheme, however. Overstepping Upper Carboniferous and Permian sediments are widespread along the SE and NE margins of the Veporic unit, partly in an allochthonous position (Markuška unit). The Alpidic cover (Foederata succession) consists of Permoscythian clastics overlying granitoids and Triassic carbonates and slates.

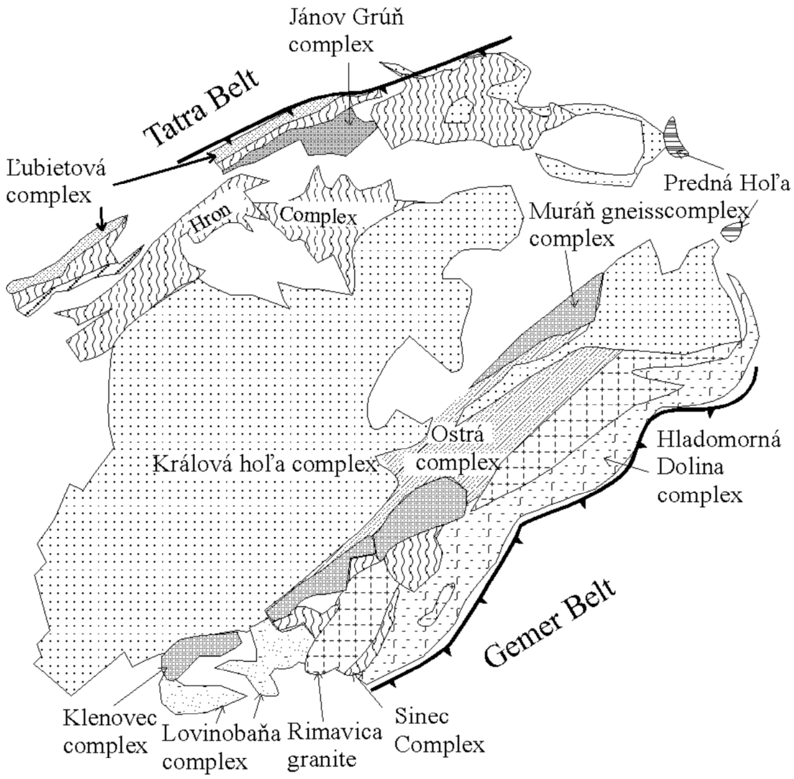

Fig. 8. Distributin of the Vepor basement rocks in the Western Slovenské Rudohorie Mts., (Simplified from Putiš in Krist et al., 1992).

All rocks in the Veporic unit are affected by intense Alpidic tectonometamorphic reworking, which records a complete Cretaceous orogenic cycle, progressing from deep burial to exhumation within the rear parts of the developing Western Carpathian orogenic wedge. The Cretaceous age of exhumation is constrained by $^{40}Ar/^{39}Ar$ thermo-chronology (Maluski et al., 1993; Dallmeyer et al., 1996; Kováčik et al., 1996), although some (highly discordant) hornblende spectra have been interpreted as Variscan cooling ages, mostly in the NW parts of the Veporic unit (Dallmeyer et al., 1996; Kráľ et al., 1996). Rb-Sr ages from granitoid rocks in the Vepor Belt range between 285-387 Ma (Cambel et al., 1988, Petrík and Kohút, 1997).

Due to Alpine overprint and reequilibration, it is difficult to establish metamorphic conditions of Pre-Alpine metamorphism in the Veporic unit. Metamorphic conditions, referred to Variscan metamorphism in the past (Krist et al., 1992) are summarized in Table 1. Putiš et al. (1997), based on metamorphic minerals in amphibolites, estimated the P-T conditions of 11 kbar and 650°C for Variscan metamorphism and 11 kbar (Fig. 9) and 500°C for Alpine reactivation in the northwestern part of the Veporicum. In gneisses and migmatites from the south-eastern part of Veporicum, PT conditions of 680-730 °C and 4-6 kbar have been estimated for pre–Alpine metamorphism (Siman et al. 1996). The micaschists form the deepest-exposed part of the basement within the Veporic unit. The mineral assemblages in the high-Al metapelites include garnet, staurolite, kyanite, chloritoid, chlorite, quartz, rutile, ilmenite and white mica (muscovite, paragonite, phengite, margarite). Their origin has been attributed to pre-Alpine (Korikovskij et al., 1989; Kováčik et al., 1997) or Alpine (Vrána, 1964; Méres and Hovorka, 1991; Janák et al., 1999; Plašienka et al., 1999) metamorphism.

Table 1. Summary of metamorphic mineral assemblages and P-T conditions from basement complexes of the Vepor Mts. (Krist et al., 1992).

	Complex	Mineral assemblage	P-T conditions
1	Ľubietová	Gr, Bt, Pl, Mu, Sil, Pl, Kf, Gr, Amph,Di	6-7 kbar 670-700 °C
2	Hron	Gr, St, Ctd, Bt, Pl, Mu, Sil, Pl, Kf, And	6 kbar 600 °C
3	Janov grúň	greenschist	400-450 °C
4	Kraľova hoľa	Gr, Bt, Pl, Mu, Sil, Pl, Kf, Ky, And	5-11 kbar 500-650 °C
5	Muráň Gneiss	Gr, Bt, Pl, Mu, Sil, Pl, Kf,	540-590 °C
6	Ostrá,	Gr, Ctd, Chl, Mu, St, Pl, Ky,	430-470 °C
7	Klenovec		530 °C
8	Hladomorná dolina	Gr, Bt, Pl, Mu, St, Pl, Cor	4-4.5 kbar 400-450 °C
9	Sinec	Mu, Chl,, Ab	
10	Lovinobaňa	Chl, Mu, Mu	
11	Predná hoľa.	Mu, Chl, Bt, Pl	

The Branisko Mts. is built up of basement rocks and late Paleozoic and Mesozoic cover formations, which are overthrust by the rock complexes of the Hronic nappes. The basement rocks with their Permian and Mesozoic cover were always correlated with Tatric units (Kamenický in Fusán et al. 1963; Maheľ 1986). On the basis of lithology, degree of metamorphism and character of igneous rocks, they are comparable with the northern Veporic units (Vozárová & Vozár, 1988). The Mesozoic sequences, which are tectonically reduced in the Branisko Mts., are lithologically identical with the sequences of the North Veporic Veľký Bok Group (Polák 1987; Polák & Jacko et al. 1997).

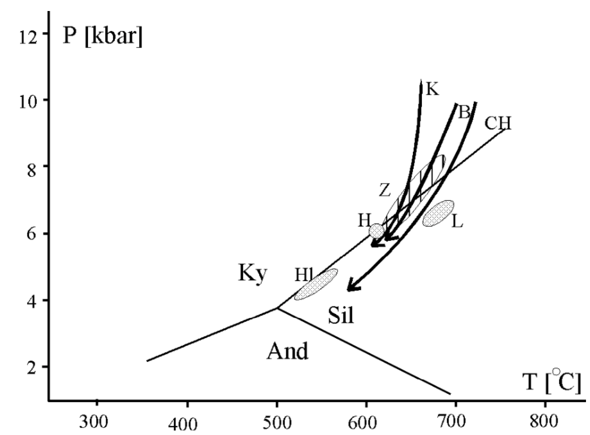

Fig. 9. Summary of P-T conditions for Variscan metamorphism in the Vepor belt basement units, including the Zemplín unit (see text for references).
H-Hron Complex
Hl-Hladomorná dolina Complex
L-Ľubietová Complex
K-Kraľová hoľa Complex
B-Branisko Mts.
CH-Čierna hora Mts.
Z-Zemplín unit

The most common basement rock in the Branisko Mts. are gneisses, migmatites, granitoids and amphibolites (Fig.10). Geochemically the amphibolites correspond to basalts and basaltic andesite. Besides hornblende and plagioclase, the amphibolites and amphibole gneisses may contain biotite, garnet and accessory amounts of apatite, zircon, titanite and epidote (Faryad, 1996). Garnet is rich in almandine (Alm_{50-57}, Grs_{25-30}, Prp_{12-22}, Sps_{1-4}, And_{1-4}) and it is slightly zoned. The Mg content decreases and Mn and Fe increase towards rim.

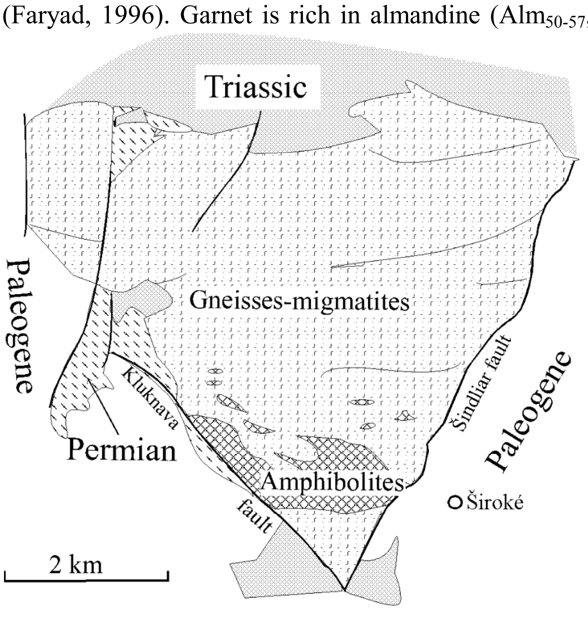

Fig. 10. Geological setting of the Branisko Mts. (based on geological map of Polák and Jacko et al., 1996).

A decrease of $Mg/(Mg+Fe^{2+})$ ratio from 30 % to 19 % from core to rim can be also observed. Maximum anorthite content in plagioclase 38 mol %. Paragneisses contain plagioclase (An_{25}), quartz, biotite garnet, muscovite, occasionally also sillimanite and kyanite (Vozárová, 1993). Garnet is rich in almandine (Alm_{71-73}. Sps_{9-10}, Grs_{1-4}, Prp_{13-15}) and indicates no compositional zoning. A fibrolitic sillimanite occurs in muscovite, rarely also in plagioclase. Metamophic conditions calculated for amphibolites are 10 kbar at 700 °C for core and of 8 kbar at 600 °C for rim composition of garnet (Faryad, 1996). Relatively lower pressures but higher temperatures were calculated for gneisses (Vozárová, 1993).

The Čierna hora Mts. represent an eastward continuation of the Vepor belt that are overthrust by the Gemer belt along the Margecany shear zone (Fig. 2, 11). Similar to other basement units in the Western Carpathians, two late-Variscan basement lithotectonic units (Upper and Lower) with diffrent P-T conditions can be distinguished (Jacko, 1998). The Upper unit, represented by Miklušovce and Bujanová complexes, consists of migmatites, gneisses, banded amphibolites and late Variscan granitoids.

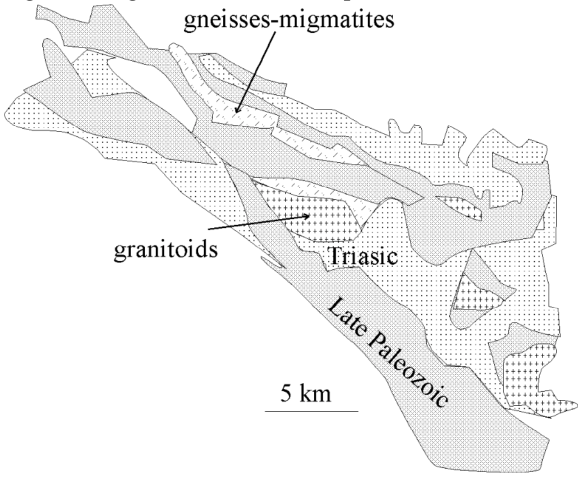

Fig. 11. Schematized geological map of the Čierna hora Mts. (Jacko, 1978).

Additional to white mica, plagioclase and biotite, the metamorphic mineral assemblages may contain K-feldspar, garnet, staurolite sillimanite and relic kyanite. The lower unit (Lodina complex), exposed in the axial part of the Čierna Hora, is formed by gneisses, amphibolites and micaschists. Following Jacko et al. (1990) and Jacko and Faryad (1998), metamorphic pressure and temperature for the Upper unit were 6-10 kbar / 675-770 °C and for the Lower unit 3 – 5 kbar/ 520-540 °C. This metamorphism is assumed to be late Devonian - early Carboniferous in age. The second metamorphic event related to granodiorite intrusions (334,5 Ma, ^{40}Ar-^{39}Ar method, Maluski et al., 1993) and occurred at 620-648 °C/ 4 kbar (Jacko, 1998). It is restricted to the Upper unit only. The later Variscan event (330-312 Ma, ^{40}Ar-^{39}Ar method) of greenschist facies condition resulted from thrusting of the lower unit onto the Upper one.

The Zemplín unit

Following Slávik (1976), the Zemplín unit is represented by basement and Late Paleozoic to Mesozoic sequences (Fig. 12). It occurs in NW-SE trending horst, and the basement rocks are exposed at the border between Slovakia and Hungary (Baňacký et al., 1989). The basement rocks in the Hungarian side were studied by (Pantó, 1965; Lelkes-Felvári and Sassi, 1981; Lelkes-Felvári et al, 1996; Kisházi and Ivancsics, 1988). Rb-Sr whole rock data from metasediments of the Zemplín unit have been interpreted in favor of a Precambrian age of the basement (Pantó et al., 1967). Muscovites from the same samples gave ages of 394 ± 52 and 450 ± 130 Ma (Rb/Sr) and 260 ± 10 Ma (K/Ar). The presumed Proterozoic age was one of the main reasons to correlate the Zemplín unit tentatively with the Eastern Carpathian basement (Grecula et al. 1981). Other authors (Slávik 1976; Rudinec and Slávik 1971; Maheľ 1986; Faryad, 1995) discussed a correlation with Variscan basement units in the central Western Carpathians (Čierna Hora or Branisko, Fig. 1, 2). Regarding lithology and metamorphic conditions, the Zemplín unit is indeed well comparable with other Western Carpathian units. Judging from the lithology and sedimentary facies of the Upper Carboniferous/Permian cover sequences, the Tatric and Veporic units of the Western Carpathians and the Zemplínicum were a part of an

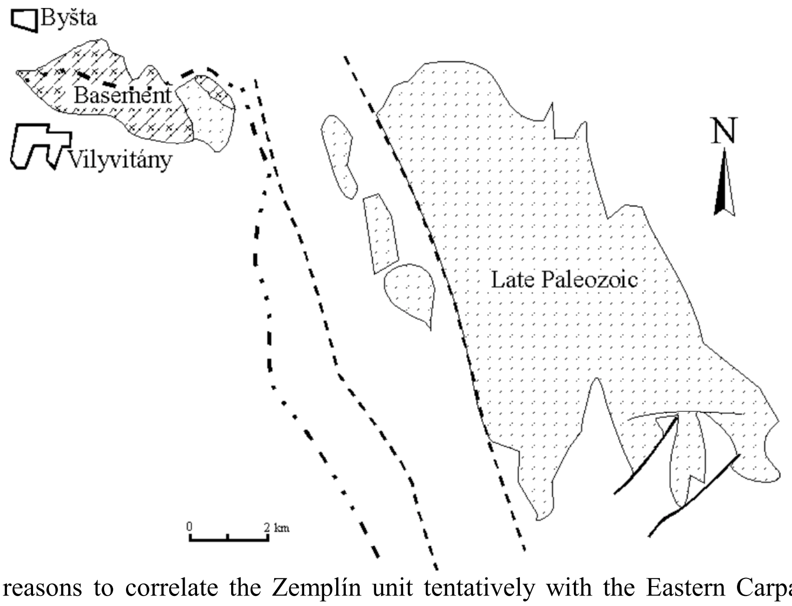

Fig. 12. Geological setting of basemen and late Paleozoic cover rocks in the Zemplín unit (compiled from Baňacký et al., 1988 and Pantó 1965).

extensional basin at the end of the Variscan orogenic cycle, and during the Alpine orogeny they were both included into the nappe structure of the Western Carpathians (Vozárová and Vozár, 1988).

The most common basement rocks are quartz-muscovite gneisses, biotite gneisses, minor graphite gneisses and rarely amphibolites. According to geochemical composition, including trace element and REE distributions, protoliths of gneisses were sedimentary sequences, comparable with shales and greywackes (Vozárová, 1991). Amphibolites, forming layers within gneisses, originated from basalts and basaltic andesite which have affinity with within-plate basalts. Ortogneisses have composition of dacite and ryhodacite (Faryad, 1995). Granitoids were found only as pebbles in late Paleozoic conglomerates. In addition to metamorphic rocks, the granitoids seem to be a complementary member of the basement lithology that is comparable with neighboring units of the Central Western Carpathians.

Metamorphic conditions, calculated using thermodynamic data of Brown et al. (1989) and Ge0-Calc Program of Berman (1988), are 650-700 ^{o}C at 6.5-8.5 kbar (Faryad, 1995, Faryad and Vozárová, 1997). These P-T conditions are inferred for most rocks exposed on surface and found in borehole. Lower metamorphic conditions (570-610 ^{o}C) are inferred for graphite gneisses are and quartz micaschists that may contains relics of staurolite.

1.2.3.2 Alpine metamorphism in the Vepor Belt

Alpine metamorphism in the Vepor Belt indicates generally southeastwards increasing to the Gemericum unit. Metamorphic mineral assemblages (phengite, chlorite, albite, microcline) in the Permian-Mesozoic cover rocks in the northern parts of the Vepor belt indicate temperature of 310-330 °C for the Podbrezová-Lopej area, 330-350 °C for Bacúch and 370-420 °C and 400-450 °C for the Kokava formation (Korikovskij et at., 1997). In the later case Sps-Alm-Grs garnet and biotite were found in granites. Metamorphic pressures of 7 - 9 kbar are inferred by phengite barometry. Similar P-T conditions are assumed for the Predná hoľa complex, which also belongs to the northern Vepor zone (Korikovskij et al, 1997).

Low-grade and medium- to high pressure metamorphism for the south Vepor area (Fig. 8) have been already inferred by Vrána (1980) who found chloritoid and kyanite in metasediments and Sps-Grs-Alm garnet in metagranites. Such metamorphic condition were latter confirmed by Méres and Hovorka, 1991, and Janák et al, 1996 who inferred about 12 kbar pressure at 550 °C for this metamorphic event. Plašienka et al. (1989, 1999) obtained relatively low-grade conditions of 300 - 450 °C and 8 kbar for the Permian metasedimentary cover complexs at vicinity of the Gemericum unit (Fig. 7). ^{40}Ar-^{39}Ar data indicated 105-115 Ma ages for amphibole and 82-89 Ma for white mica (Dalmayer et al., 1996; Kováčik et al (1997). The first ages are assumed to represent regional metamorphism and the later are interpreted as a result of uplift and unroofing of the Vepor units.

Alpine metamorphism in the Čierna hora Mts. was investigated in the Upper Carboniferous cover sandstones in the northeastern periphery of the Čierna Hora Mts. The sandstones are characterized by the presence of metamorphic white mica and albite for that 250-270 °C temperatures are assumed (Korikovskij et al, 1989). Alpine metamorphism in Zemplínicum has not been investigated in detail. Based on metamorphic minerals in the Upper Carboniferous sequences (white mica, chlorite, albite; Vozárová and Vozár, 1988, Kobulský et al., 1989), P-T conditions similar to that in Čierna hora can be assumed for the Zemplín unit.

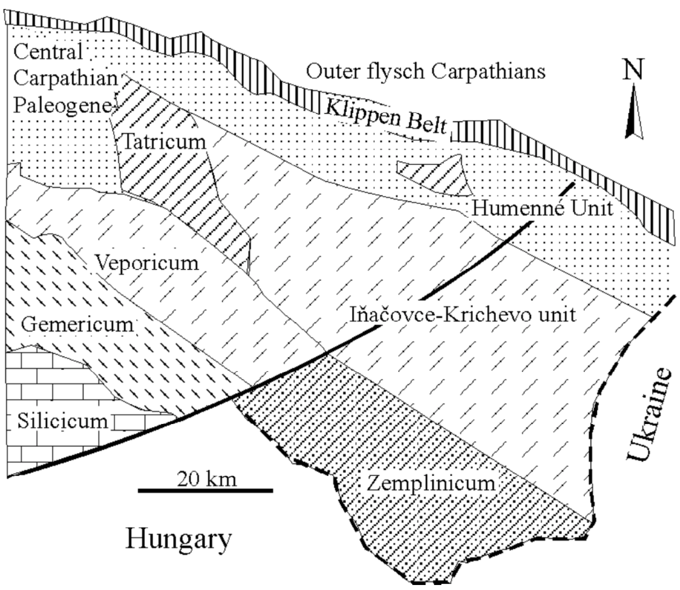

Fig. 13. Geological Sketch of the pre-Neogene units in the eastern part of the Western Carpathians (Baráth et al., 1997).

The Inačovce-Kričevo unit

The Inačovce-Kričevo unit (Fig. 13) is specific for its basement lithology that belongs to pre-Neogene sequences (Upper Triassic-Middle Eocene) of the Eastern Slovakian basin. They are represented by variegated phyllites that can be correlated with Triassic and Jurassic-Cretaceous Bünderschiefer formation (Soták et al., 1994). The most common rocks are phyllites (metasandstones, metasilstones) and rarely also metabasites and serpentinites that are assumed to represent oceanic lithologies. Metamorphic mineral assemblages are phengite, chlorite, albite, paragonite, chloritoid, biotite and actinolite for that temperature and pressure of 350-400 °C and 5-7 kbar are estimated

(Biroň et al., 1997). Zircon fission track data indicated postmetamorphic cooling of the Inačovce-Krichevo unit during early Miocene time (Soták et al., 1993).

1.2.4. The Gemer Belt

The Gemer Belt is represented by Early Paleozoic basement and Late Paleozoic to Middle Triassic cover sheet, late Paleozoic-Mesozoic Meliata unit, superficial Silica nappes and Senonian-Tertiary post-nappe cover. It tectonically overlies the Vepor Belt along the Margecany-Lubeník shear zone (Andrusov, 1968; Jacko, 1979; Bajaník et al., 1983; Grecula, 1982) (Fig. 14). The basement consists of greenschist facies sedimentary and volcanic rocks that are intruded by Permian granites (Kovách et al, 1986) in the central parts. Some thrust slices and blocks of amphibolite-facies rocks (the Gneiss amphibolite complex of Dianiška and Grecula, 1979 and Faryad, 1990 or Klátov Group of Hovorka et al., 1984) tectonically overlie the greenschist facies rocks in the northern and eastern parts of the Gemericum (Fig. 14).

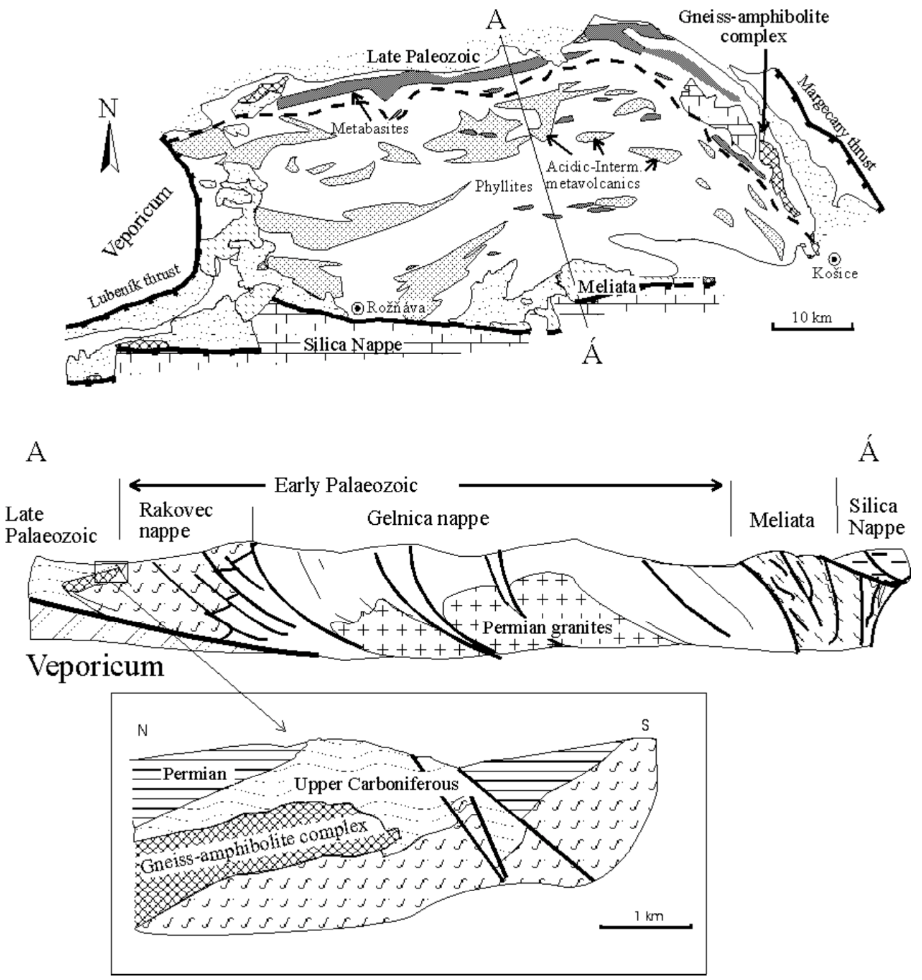

Fig. 14. Schematized geological map of the Gemericum with cross-section through the main units. (Dashed line in the map separates the Rakovec Group to the north from the Gelnica Group to the south).

The greenschist facies basement is represented by two groups (Gelnica and Rakovec) which are different in lithology. The Gelnica Group occupies more than 2/3 of the area and occurs in the central and southern parts of the Gemer Belt. It consists of metasediments (quartz phyllites, metapelites, black phyllites and interbedded marbles) and acid to intermediate volcanics. Only small amounts of basaltic rocks are present in this group. Conversly in the Rakovec Group basaltic rocks are abundant and acidic volcanic are less common. The basement rocks together with late Paleozoic and Mesozoic sequences are characterized by southward dipping thrust zones and penetrative cleavage that are supposed to be the result from Alpine tectonic movements (Rozložník, 1965; Snopko, 1964; Jacko, 1979; Grecula, 1973, 1982).

1.2.4.1 Pre-Alpine metamorphism in the Gemer belt

Metamorphosed basic rocks were derived mostly from basalts, basaltic tuffs and minor amounts from gabbro or dolerite that may contain relic igneous pyroxene. The most common metamorphic minerals in metabasites are albite, epidote, chlorite, actinolite and titanite. Some rocks also contain stilpnomelane and biotite. Calcite is usually present in actinolite-free varieties. The Na_2O content in amphibole is usually low (0.1 - 0.8 vol. percent). Some metabasites from the northern part of the Gemericum unit contain Na-rich actinolite or Na-Ca amphibole. The latter amphibole, first found in metabasalts in the Rakovec locality, corresponds to the subsilicic taramite (Hovorka et al., 1988; Faryad and Bernhardt, 1996). It coexists with albite, epidote (al = $Al/(Al+Fe^{3+})$ = 0.20-0.30), Ca-garnet (Grs_{73}, And_{18}, Sps_2, Alm_2, $Py_{0.2}$.), titanite and biotite. Coarse grained taramite is weakly zoned and reveals a decrease of Al and an increase of Fe^{3+} from core to rim.

Acidic-intermediate metavolcanic rocks are mostly represented by primary tuffs, but lavas and subvolcanic varieties are also present. The metamorphic minerals are quartz, albite, white mica, chlorite and, rarely, biotite. K-rich rocks may contain also microcline. White mica composition depends on the whole rock chemistry. Phengite with Si = 3.3 atom/formula unit (a/f.u.) occurs in metadacite, but K-rich metarhyolite usually contains muscovite. Some Al-rich tuffaceous varieties (probably a mixture of volcanic and sedimentary rocks) contain muscovite, iron-rich chloritoid ($Fe^{2+}/(Fe^{2+} + Mg)$ = 0.87-0.88) and pyrophyllite (Varga, 1973; Korikovskij et al., 1992; Faryad, 1995). The presence of chloritoid is mostly restricted to the southern and eastern parts of the Gemericum unit. Relation of chloritoid to Variscan or Alpine metamorphism is not well clear, but the presence of this mineral in the Late Paleozoic rocks favor its Alpine origin.

The most common rocks of sedimentary origin are phyllites, which derived from sandstones, greywackes, pelites and black shales. Marbles and lydites (quarzites with high amount organic matter-graphite) from intercalations in black shales. Metapelites and metapsammites are characterized by monotonous metamorphic mineral assemblages, which contain quartz, white mica, chlorite and rarely also albite. In the southern and eastern parts of the Gemericum unit, they also contain chloritoid. White mica is mostly phengite in composition and with Si contents of 3.15-3.30 a/f.u. A low- Si content for white mica is, however, assumed based on the b_0 values obtained by Sassi and Vozárová (1987) and Mazzoli and Vozárová (1992). Paragonite was detected by powder diffraction analyses.

Mn-rich carbonate rocks that underwent greenschist facies metamorphism were investigated at three localities in the central part of the Gemericum unit (Faryad, 1994). They contain rhodonite, calcite, Mn-calcite, spessartine-rich garnet (Sps_{60-90}, Grs_{10-30}, Alm_{0-15}) pyroxmangite, knebelite, biotite, phengite, chlorite, manganoan actinolite and tirodite. As retrograde phases, these rocks include caryopilite and manganpyrosmalite.

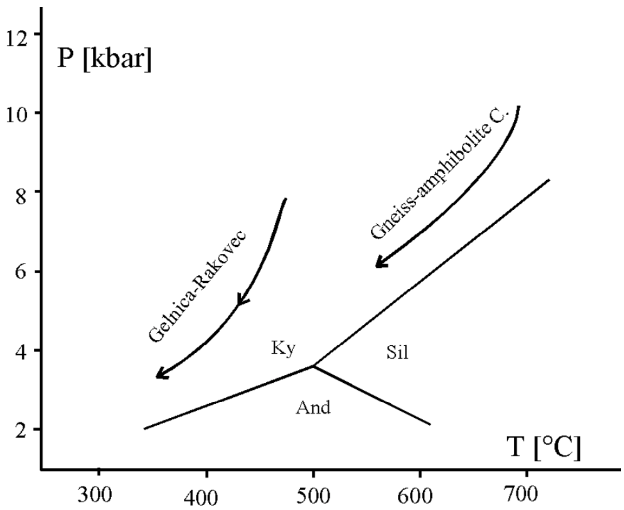

Fig. 15. P-T conditions estimated for Variscan metamorphism for basement rocks in the Gemericum (Hovorka et al., 1980; Faryad, 1990).

Metamorphic temperatures estimated from mineral compositions and from petrogenetic grids for most area of the Gemericum unit are 350-450 °C (Fig. 15) (Varga, 1973; Faryad, 1991; Korikovsky et al, 1992). Microprobe analyses of white mica, suggest pressure of 3-5 kbar for the central and southern area of the Gemericum unit (Faryad, 1995). Because of the low-grade Alpine overprint, relations of mineral assemblages to Pre-Alpine or Alpine metamorphism are not clear. Pre-Alpine assemblages were probably preserved in some unfoliated igneous bodies (intrusions or lava flows). Pressures of up to 6-8 kbar at 440-480 °C are estimated for taramite-bearing metabasalts near Rakovec village (Hovorka et al, 1988; Faryad and Bernhardt, 1996).

The **amphibolite facies rock slices (Gneiss-amphibolite complex = Klátov nappe)** show mostly north dipping tectonic contact with underlying greenschist facies rocks (Fig. 14). Both greenschist and amphibolite facies rocks are covered by Upper Carboniferous conglomerates which contain pebbles of both underlying greenschist and amphibolite facies rocks (Vozárová, 1973). Besides the most common amphibolites and plagioclase gneisses, some serpentinites, occurring at contact with underlying greenschist facies rocks and marbles intercalated in amphibolites are also present. Metamorphic minerals in amphibolite are amphibole, plagioclase and partly garnet. In addition to plagioclase and quartz the gneisses may contain amphibole, garnet and biotite (Rozložník, 1965, Dianiška and Grecula, 1979, Hovorka et al., 1984, Faryad, 1990). An occurrence of amphibolite and gneiss, overprinted by high-pressure low-temperature metamorphism was described from Rudník (Faryad, 1988), but their genetic relation to gneiss-amphibolite complex is not clear. P-T conditions of Pre-Alpine metamorphism for amphibolites and gneisses obtained by thermobarometric calculations are 6-10 kbar at 650-700 °C (Hovorka et al., 1980; Faryad, 1990)

1.2.4.2. Alpine metamorphism in the Gemer belt

Because of low-grade metamorphism in the Gemer basement during both Pre-Alpine and Alpine events it is hardly to distinguish mineral assemblages formed by pre-Alpine or Alpine metamorphism. P-T conditions of Alpine metamorphism can be additionally to Late Paleozoic to Mesozoic cover sequences estimated from Permian granites that contain metamorphic garnet, phengite, chlorite, K-feldspar and albite. The garnet has composition (1/3 Alm + for 1/3 Sps + 1/3 Grs) (Faryad and Dianiška, 1989) similar to that reported by Vrána (1980) from the Vepor Belt. P-T conditions estimated for this assemblage are 6-8 kbar at 300-350 ^{o}C (Fig. 7, Faryad and Hoinkes, 1998). Al-rich rocks, overprinted by contact metamorphism, contain corundum, andalusite and kyanite. The kyanite probably belongs to Alpine metamorphism. Alpine overprint in the Gneiss amphibolite complex rocks can be assumed by newly formed grassular-rich garner rimming amphibolite facies garnet.

The upper Carboniferous cover rocks at Ochtiná in the vicinity of Veporicum, for which greenschist facies conditions are assumed (Korikovskij et al, 1997), are characterized by the presence of phengite, K-feldspar, chlorite and chloritoid. Ar-Ar data obtained for white mica from the Late Paleozoic metasediments gave 86-101 Ma age (Dalmayer et al., 1996).

1.3. The Inner Western Carpathians

The Inner Western Carpathians represent Paleozoic and Mesozoic sedimentary, mostly carbonate complexes showing affinity to the Alpine-Dinaric facies belts (Kozur and Mock, 1973). In the Slovak territory, they form three nappe piles from top to bottom are: the Silica nappe, Turna nappe and the Meliata unit that overthrust the Paleozoic sequences of the Gemericum to the north (Fig. 16, 17). The Meliata unit is interpreted as suture zone formed by closure of the Triassic Hallstatt-Meliata oceanic basins. It consists of numerous slices and olistolites, platform carbonatic, pelagic oceanic sediments and dismembered ophiolites and blueschists (Reichwalder, 1973; Faryad, 1995a, b, Hovorka et al., 1985; Harangi et al., 1996; Dosztály and Józsa, 1992, Árkai, 1993, Mazzoli et al., 1992; Mello et al., 1997, Horváth, 1997). Following Kozur and Mock (1997), the northern occurrences of the Meliata rocks at Jaklovce and Dobšina represent a northern branch of the Meliata oceanic basin.

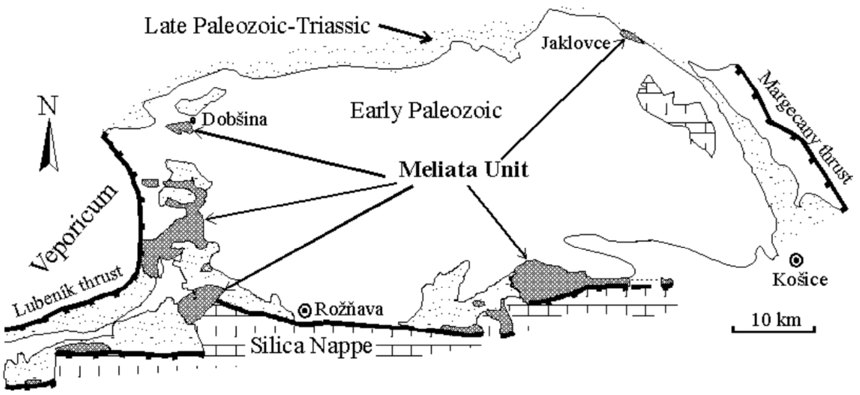

Fig. 16. Surface occurrences of the Meliata unit in the Slovak territory.

The Meliata rocks, occurring in the southern part of the Gemericum unit, show steeply dipping, generally fan-wise imbricate structure. Their upper parts have been partly incorporated into an evaporitic mélange. Blueschists (called by Mello as the Bôrka nappe), tectonically overlying Paleozoic of the Gemericum unit and serpentinites, form slices within very low-grade sedimentary rocks (Fig. 18).

On the basis of geological position and metamorphic history, the blueschist facies rocks are subdivided into four groups (Faryad, 1995a, b): I) Marbles intercalated with metabasalts and glaucophane-bearing phyllites constitute the most common group, which occurs at Radzim, Štítnik, Bôrka, Hačava and Šugov. The marbles and metabasites are usually associated with phyllites that may contain glaucophane; II) Glaucophane- free quartz phyllites (lower complex), exposed near Jasov and Šugov are overlain by marbles with metabasites (upper complex). They originated from psammites and conglomerates; III) Amphibolite and amphibole garnet gneisses, overprinted by blueschist-facies metamorphism at Rudník, were derived from basement unit. Some metabasites and micaschists without marble (probably also basement rocks), tectonically overlay the late Palaeozoic cover sequences of the Gemericum unit at Zádiel; IV) Blocks of metagabbro in the evaporite melange of the Turňa nappe were found near Bohuňovo in the Slovak territory (Faryad and Dianiška, submitted to print) and in Hungary (Horváth, 1997).

Metabasalts of *group I* have geochemical characteristics indicative of island-arc basalts transitional to mid-ocean ridge basalts (Faryad, 1995b, Ivan and Kronome, 1996). Blue amphiboles from metabasite have composition of glaucophane-ferroglaucophane, rarely also riebeckite. Phengitic white mica phyllites shows high Si-contents in the range of 3.42-3.53 atoms per formula unit (a.f.u.; calculated on 11 anions). Progressive increase of metamorphic pressures and temperatures is interpreted from mineral zoning and textural relations in these rocks. P-T conditions up to 12 kbar and 460 ^{o}C can be estimated for the most blueschist-facies assemblages in both metabasalts and phyllites (Fig. 19). ^{40}Ar-^{39}Ar dating both for metabasites and phyllites gave Middle Jurassic age of 151.9 -155 Ma.

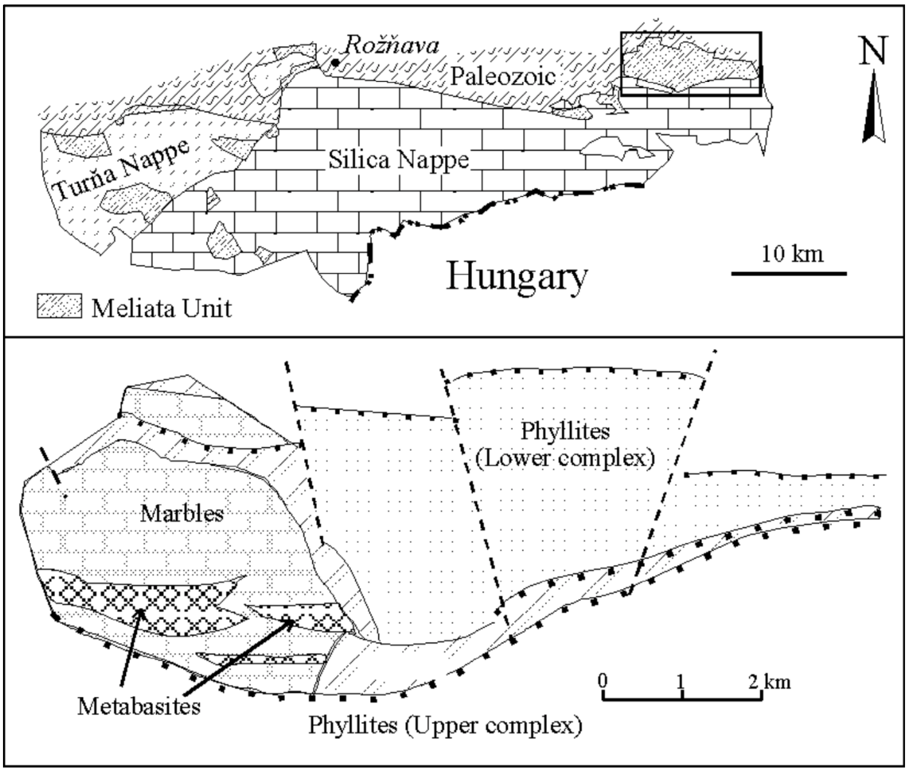

Fig. 17. Geological map of the Meliata unit in the southern part of the Gemericum (modified from Geological map of Mello et al., 1997 and Reichwalder, 1973).

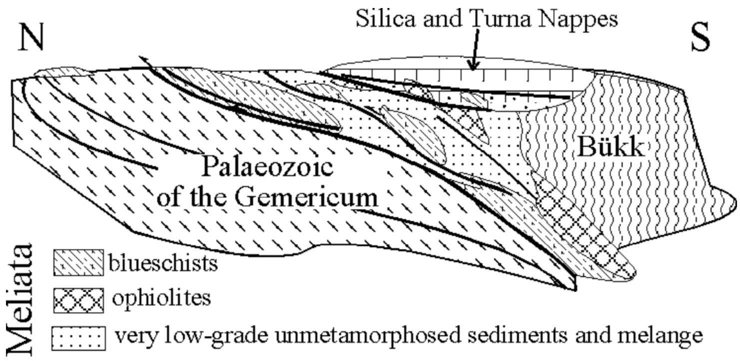

Fig. 18. Schematized cross-section, indicating geological position of the Meliata unit.

Table 2. Mineral assemblages in blueschist from the Meliata unit.

Rock type	Group 1		Group II	Group IIIb		Group IIIb	Group IV
	Metabasite	Phyllite	Phyllite	Metabasite	Micasch.	Amphibolite	Metagabbro
Glaucophane	***	(*)		***	*	**	**
Epidote	***	(*)		***	*	**	***
Albite	***	*	(*)	***	*	**	***
Chlorite	*	*	*	*	**	**	**
Phengite	*	***	***	*	***	*	*
Paragonite	*	*	*	*	*		
Quartz	*	**	**	*	**	*	*
Titanite	*	(*)		*	*	*	*
Actinolite	(*)			(*)			*
Na-Pyroxene	(*)	(*)		(*)			
Garnet	(*)	(*)					
Chloritoid		(*)	*	(*)	*		
Rutile		*	*	*	*		

Estimated modes of minerals: ***> 20 %, **> 5 % *- rarely present phase.

Group II rocks of the lower complex are quartz phyllites derived from sandstones and quartz conglomerates, and phyllites derived from pelites and psammites. These rocks contain no glaucophane. The Si-content in phengites is 3.26-3.51 a.f.u. Relatively low P-T conditions of 10 kbar at 350-370 ^{o}C were estimated for rocks of the lower complex. Two Ar-Ar ages of 172 and 222 Ma were obtained for phengite from metaconglomerates and phyllites (Faryad and Henjes-Kunst, 1997). Low-temperature overprint (ca. 80-90 Ma) assumed from disturbed age spectra is tentatively related to Cretaceous nappe emplacement in the Western Carpathians (Kantor, 1960; Maluski et al., 1993; Dallmayer et al., 1996). In the Meliata unit, this age seems to be loading and thrusting result of the Silica and other higher nappes to the north.

The *group III* rocks at Rudník are amphibolites and garnet-bearing hornblende gneisses. Blue amphibole and high-Si phengite document a blueschist-facies overprint. During blueschist- facies metamorphism of group VI rocks P-T conditions similar to those of group I rocks are inferred.

Metabasites of *group III* blueschist at Zádiel show a chemical affinity to within-plate basalts. Characteristic minerals of metabasites and micaschists are listed in Table 2. Two varieties of white mica were distinguished in quartz-rich micaschists: a coarse- grained low-Si muscovite (3.1 a.f.u.) and a fine-grained high-Si phengite (3.35-3.5 a.f.u.). The coarse-grained mica indicating early Paleozoic Ar-Ar age of 375 Ma (Faryad and Henjes-Kunst, 1997), is partly rimmed by high-Si phengite. Randomly oriented glaucophane crystals, cross-cutting the coarse-grained muscovite, indicate that blueschist facies metamorphism was not accompanied by pervasive deformation. Metamorphic conditions of 450-460 ^{o}C at 10-12 kbar were calculated for this group rocks.

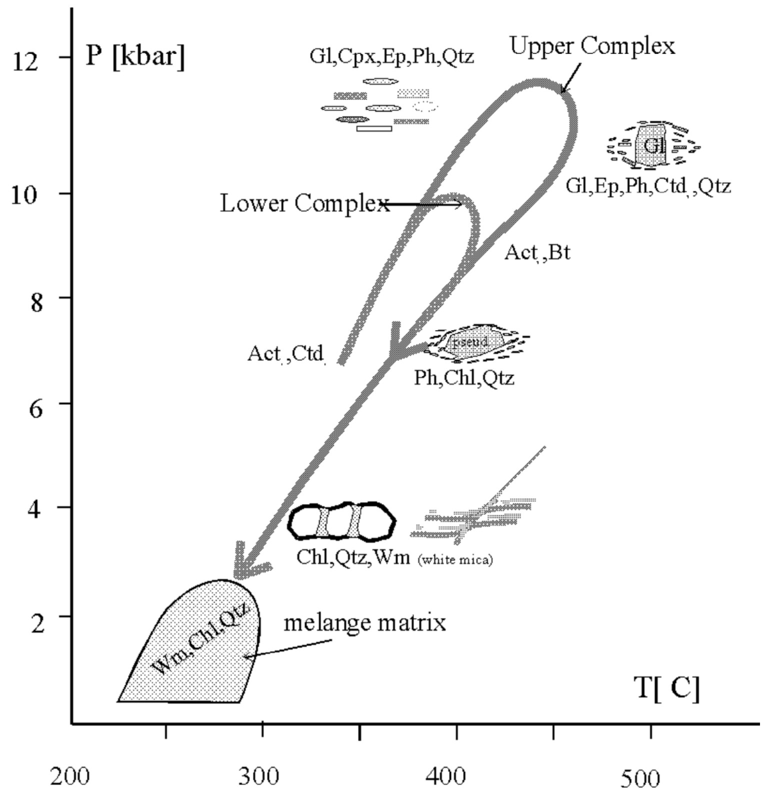

Fig. 19. Schematic P-T diagram showing relationships between deformation and mineral crystallization. Inferred P-T conditions of melange matrix is also shown. Act_1-actinolite rimmed by glaucophane, Cdt_1-chloritoid inclusion in glaucophane.

Metagabbro *group IV* from the evaporite melange in Bohúňovo indicates affinity with alkaline basalts. It contains relic igneous richterite and five varieties of metamorphic amphiboles (winchite, edenite, magnesiohornblenede actinolite and riebeckite). Other minerals are epidote, albite, K-feldspar, phengite and titanite.

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