Tectonometamorphic evolution of the Branisko and Čierna hora Mts. (Western Carpathians)

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Abstract. Four tectonothermal events have been recognized throughout either Variscan and Alpine tectonometamorphic development within Branisko and Čierna hora Mts., i.e. at the eastern margin of the Western Carpathian Internides realm. Based on palynological and geochronological data the first three Variscan events can be correlated with late Devonian - Early Carboniferous interval. The youngest Variscan event-the consequence of creation of Variscan nappe structure of Tatric and Veporic basement, has been dated to Late-Early Carboniferous boundary.

According to field and geochronological data the first two Alpine tectonometamorphic stages are of pre-Gossau (likely Valangian-Albian) age. The third-the Late Cretaceous one, is probably product of pre -Late Campanian uplift of the Veporic metamorphic dome. The youngest, the post-Eocene event apparently connects with Early Miocene oblique collision of the Western Carpathian Internides with the Northern European Platform.

Key words: Upper and Middle Variscan units, Tatricum and Veporicum units, Variscan and Alpine metamorphism

Introduction

Despite the crosswise position of the Branisko and Čierna hora Mts. in the NE-SW structure of the Western Carpathian Internides (WCI) both the mentioned mountains comprises principal lithostructural suites of the Tatric and Veporic domains (TVD) of the WCI and thus represents direct - the eastern, continuation of the Tatric and Veporic units. Latest geochronological and thermobarometric data obtained throughout the WCl territory and new field mapping and structural results from the Branisko and Čierna hora Mts. region require to reexamine the previous views on tectonometamorphic evolution of the region.

On the basis of the mentioned results this paper reevaluates the available data about the structure, TP conditions and succesive relationships of the Variscan and Alpine tectonometamorphic events of the region with an attemp to synchronize the Alpine events with the Cretaceous development of the VCl Veporic metamorphic dome.

Geological setting

The Branisko and Čierna hora Mts. form the eastern margin of Tatric and Veporic domains of the Western Carpathian Internides (WCl). Their structure comprises two the Late -Variscan basement nappe sheets of the mentioned domains, namely the Upper lithotectonic unit (ULU) and the Middle lithotectonic unit (MLU) sensu Bezák (1994). The ULU consisting of migmatites, gneisses, tiny amphibolite intercalations and granitoid bodies composes the exposed Tatric basement of the Branisko Mts. and the top part of the Veporic basement (the Miklušovce and Bujanová complexes) of the Čierna hora Mts. Lodina complex representing the MLU is outcropped in the axial part of the Čierna hora Mts. basement only. It consists of diaphtoritised gneisses, scarce lensoidal amphibolites and a tiny strip of micaschists rimming the SW flank of the MLU.

Cover sequences are build of Permian to Early Triassic clastic sediments in the Branisko Mts. and by Late Carboniferous to Malmian formations in the Čierna hora Mts. respectively. The units are topped by klippes of the Choč nappe pile and/or by Paleogene and Neogene postnappe sequences.

In the adjoining Gemeric unit litostratigraphical sequences of the Gelnica unit, Rakovec unit, Klatov nappe unit, Late Carboniferous to Early Triassic cover formations, Meliata (Jaklovce) unit and Silica nappe klippes are present (Fig. 1 a, b, c).

All the units are more or less incorporated into the Alpine NW-SE regionally expressive fold/fault structures which successively culminate into a development of an imbricate melange within the NW-SE Margecany shear zone located between the Gemeric unit and theVeporic unit of the Čierna hora Mts.

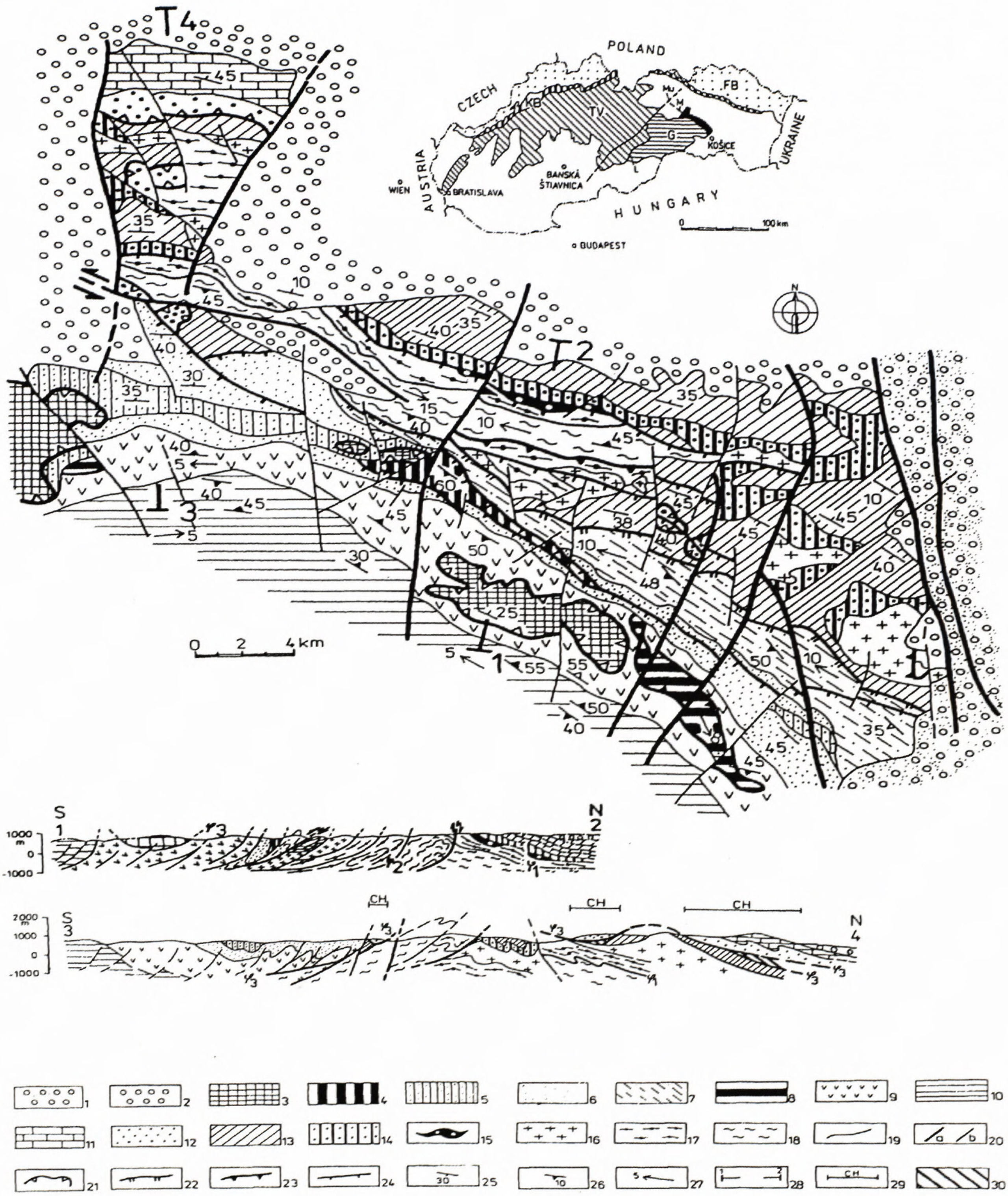

Fig. 1. (a) Position of the studied area in the Western Carpathians.
FB - Flysh Belt, KB - Klippen Belt, TV - Tatricum and Veporicum units, G - Gemericum unit, Mu - Muráň fault, L - Lubenik shear zone, M - Margecany shear zone, black strip - studied area position

Fig.1 (b-c) Geological map and cross sections of the studied area.
1 - Neogene molasse sediments, 2 - Flysh successions of the Intra Carpathian Paleogene, 3 - Silica nappe carbonates, 4 - Sediments and matabasites of the Jaklovce succession of the Meliata unit, 5 - 10 Gemericum unit, 5 - Early Triassic shales, 6 - Permian clastic sediments, rhyolitic volcanites and evaporites, 7 - Carboniferous flysch metabasite sequence with conglomerate and carbonate intercalations, 8 - Klatov group gneisses, serpentinites and amphibolites, 9 - Metabasalts and phyllites of the Rakovec group, 10 - Sandstones, phyllites and rhyolite volcanites of the Gelnica group, 11-12 - Choč nappe of the Hronicum unit,

Thus within 4 to 8 km cross section line nearly all principal structural units of the WCl - and their structural relationships, are observable. Those realities and some biostratigraphical and geochronological data permit a relatively objective successional calibration of tectonometamorphic events - at least of the region.

Variscan tectonometamorphic events

According to palynological and geochronological data (Čorna and Kamenický, 1976, Jacko and Baláž, 1993) metamorphic rocks of both the ULU a MLU are of the Devonian age. Biotitic granodiorites of the ULU (the Bujanová complex) were dated by Ar-Ar method to 334,5 Ma (Maluski et al., 1993). Thrusting of ULU over MLU has ben stated by Dallmeyer (Ar-Ar method, pers.inf.) to 330-312 Ma. Clasts of both mentioned nappe sheets are present within Late Carboniferous cover formation, thus discussed data are the limits for the time interval of four Variscan tectonothermal events recognized within basement units of the region.

TP conditions of the first Variscan tectonometamorphic event of the ULU have been determined by Vozárová, (1993) to 675-770^0 C and 630-870 MPa. They are also indicated by 0-24% pyrope molecule content in garnet cores and by restites of kyanite within ULU gneisses (Vozárová, 1993, Jacko et al.1990).Similar temperatures, but relatively higher pressures were obtained from garnet cores (700^0 C and 1000 MPa of amphibolites (Vozárová - Faryad, 1997) It is usefull to add that mineral assemblage of the event is broadly replaced by the mineral paragenese of the following event within the ULU. Evidently lower TP parameters within the underlying MLU sheet (the Lodina complex) i. e. 520-540^0 C and cca. 300 MPa reveal amphibolite facies metamorphic conditions (Fig.2). According to Korikovskij et al., (1990) Bt+Mu+Pl+Kfs+ Q±Gt is representative mineral assemblage for two-mica gneisses of the event in the MLU, while Hb+Pl+Ilm+ Aph±Q assemblage typical for amphibolites. Bt+ Mu+ Gt +St+Q ±Pl±Andl. form the assemblage of two-mica schists.

The second Variscan tectonothermal event - the periplutonic one, is known from the ULU only. It has very close TP conditions in metamorphic rocks of both the Branisko and Čierna hora Mts. (590-648^0 C and 300-400 MPa, Vozárová (l.c.) and/or 620-625° C and 400-450 MPa, Jacko et al., 1990, respectively). Following Vozárová (l.c.) Gt+Bt+Ksf+Pl±Sil are charakteristic for the Branisko gneisses and migmatites. In the Čierna hora Mts. part of the ULU Jacko et al. (1990) stated the following representative mineral parageneses of this event for typical rock suites: Bt+Pl+Kfs+Q±Gt±Sil for gneisses and migmatites, Hb+Pl+Sph±Cl_z±Ilm±Q for amphibolites and Hb_{Mg}±Phl±Zs±Carb±Serp(Ta?) for rare metaultrabasite bodies.

The third metamorphic events is exclusively bound to relatively narrow exocontact zones of relatively younger autometamorphic granite of the ULU, where its Ksf +Mu ±Pl±Bt paragenese replaces mineral assemblage of the second event and mineral association of biotite granodiorite as well.

The last Variscan tectonometamorphic event producing the diaphtoritic paragenese Q+baueritic Mu+ Chl±Ep, is connected with Early Carboniferous overthrusting of ULU onto MLU. This event - at least partly, diaphtoriticaly homogenized mineral paragenesis of the previous events at green schists facies metamorphic conditions (Fig. 2).

Alpine tectonometamorphic events

The absence of Cretaceous formatios in the cover sequence of the Veporic unit of the region and 135,7 Ma Ar-Ar age obtained from muscovite of the mylonitic granodiorite of the Bujanová complex (Maluski et al., 1993) indicate the begining of the Alpine tectonometamorphic events. Analogously as in the central part of the WCl the intensity of the Alpine metamorphism of the region culminates in its Veporic domain. However, unlike the central part of the Veporic dome (cf. Plašienka, 1997), TP conditions of all-the four (AD_{1-4}) tectonometamorphic events recognized in basement rocks of this domain of the Veporic unit did not overlapp a middle level of the green-schist facies metamorphism. Cover sequences have been metamorphosed at the lower boundary of this metamorphic facies and the Choč nappe pile even at the anchizonal conditions (Korikovskij et al. 1992).

11 - Late Carboniferous clastic sediments, 12 - Triassic and Jurassic carbonates, 13 - 15 Cover sequences of the Tatricum and Veporicum units, 13 - Triassic to Late Jurassic - prevailingly carbonate, successions, 14 - Permian greywackes, shales and rhyolite volcanites, 15 - Late Carboniferous clastic sediments, 16 - 17- The Upper unit of the Variscan structure of the Tatric and Veporic crystalline complex, 16-granitoids of the Patria complex (the Branisko Mts) and the Bujanová complex (the Čierna hora Mts). 17 - migmatites gneisses and amphibolites of the Patria, Bujanova and Miklušovce complexes 18 -The Middle unit of the Variscan structure of the region diaphtoritised gneisses and amphibolites of the Lodina complex (in the Veporic basement only) , 19 - Geological boundaries, 20 - Normal faults, a - regionally significant, 21 - Soles of the Alpine nappes (φ_3 in cross sections only), 22 - Margecany shear zone,23 - Alpine reactivated sole of the Late Variscan nappe (φ_2 in cross sections only), 24 - others important shear zones, 25 - bedding position, 26 - Alpine schistosity orientation, 27 - Alpine fold axes orientation, 28 - Cross sections lines, 29 - Choč nappe extent (in cross sections only), φ_1 - sole of the Late Variscan nappe (in cross section only). 30 - The Križná nappe sequence (in cross section only).

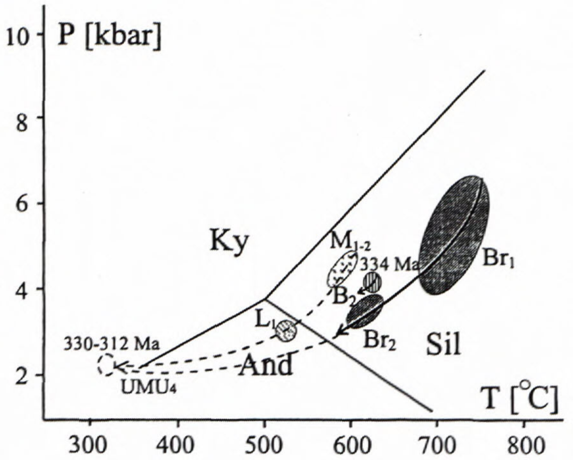

Fig. 2. P-T conditions of the Variscan metamorphism of Upper (Br, M, B) and Middle (L)- the Late-Variscan lithotectonic units of the region. A retrogressive path (dashed) of the fourt Variscan tectonometamorphic event illustrates the Late Variscan green-schists facies convergency of mineral parageneses of both mentioned (UMU) units within their shear-contact zone. Br-metamorphic rocks of the Patria complex (the Tatric unit of the Branisko Mts.) M,B,L-metamorphic rocks of the Veporic unit of the Čierna hora Mts. (M-the Miklušovce complex, B-the Bujanová complex, L-the Lodina complex), 1-4: Succession of the Variscan tectonometamorphic events. See text for further explanations.

Structural products of the first - the pre -Gossau (the AD_1) tectonometamorphic event are both E-W recumbent folding of cover sequence and diaphtoritized suite of the MLU and NNE vergent thrusting of the Choč nappe (Jacko et al. in Polák et al. 1997). Within axial clea- vage set of folded MLU suite and marly Jurassic limestones synkinematic assemblage of chlorite, white mica, quartz and carbonate minerals is locally preserved.

During the AD_2 event all the units of the region, incl.the Choč and Gemeric ones, have been penetratively folded into NW-SE folds. For this event is typical a post-kinematic blastesis of Chl+Mu+Q±Pl±Tourm, assemblage within the folds in the basement units namely in diaphtorites of the MLU.The fold structure of the pre-Tertiary units has been successively shared within regional (e.g.Margecany) reverse shear zones of the same direction.

Within the AD_3 - the pre - Gosau event as well, structures of the NW-SE shear part have been opened for a hydrothermal mineralization and rarely -within wider silicified zones of the MLU basement rocks, resulted into postkinematic growth od Q+Mu+Bi± Ab.

The AD_4 event comprises an expressive, post -Paleogene mainly sinistral wrenching of the previous structure of the region. Dominant strike slip zones within all the units are several 10 m thick, they have NW-SE orientation and moderate to steep dip to SW (Figs.1 b,c). They commonly reactivate reverse shear zones of the AD_2 event. On cleavage planes of the zones synkinematic growth of chlorite, carbonate minerals, white mica and ± quartz assemblage is typical.

Discussion and conclusions

As results from above outlined data the Late Devonian - Early Carboniferous interval documents a very short limit for the Variscan tectonometamorphic development of the region. Following Maluski's et al. (1993) 334,5 Ma Ar-Ar dating of granodiorite from the Veporic part of the ULU we obtain the upper limit for the first event because sheet-like granodiorite bodies penetrate into schistosity - i.e. into subparallel cleavage set, of the tightly folded metamorphic rocks of the unit. For a comparison it is usefull to add that the granodiorites either petrochemically or in age are very close to better known Veporic granodiorites of the Sihla type (cf. Petrík et al., 1993).

Palynological determination of the Devonian age of the ULU metamorphic rocks of the region (Čorna and Kamenický, 1976) has been dated from gneisses overlying the granodiorite body. As it is known from Bezák's (1994) definition of the Variscan nappe structure of the TVD, the ULU is a collage of either genetically or in age different rock with a thick complex of paleo-Variscan migmatites (orthogneisses) and-originally, lower crustal, banded amphibolites floored sheet-like granitoid bodies of the ULU (Bezák et al.1997, Hovorka et al., 1992, Janák et al., 1993). From this point of view it is possible that some lamellae of relatively younger rock suites are present within gneissic-migmatitic complex of the ULU. Nevertheless, before the emplacement of granitoides, the whole suite of the ULU have been either tightly folded into E-W folds or synkinematically metamorphosed at amphibolite to granulite facial conditions (Vozárová 1993, Janák et al., l. c., Bezák et al., l. c.). Structural parameters of this event reveal its formation in a simple shear regime (Jacko et al., 1997). Typical structures of the event are tight, rootless cm-dm folds. Their axial plane cleavage set practically obliterates the earlier structures.

A very close linkage of the second Variscan metamorphic event to the granitoid bodies emplacement is indicated by: (i) a gradual increase of migmatitization phenomena towards granodioritic bodies (Jacko, 1978), (ii) - a substitution of kyanite by sillimanite and by evolution of garnet retrograde rims in gneisses (Jacko et al., 1990, Vozárová, l.c.), (iii) - a mimetical growth of phyllosilicates of the event onto schistosity planes of the rocks (Jacko, l.c.). The temperature of the event in the Veporic part of the region - i.e. 630-625 °C correlates to initial temperatures of granodioritic melt - i.e. 850-600 °C, gained from analytical researches of zonal zircons (Jablonská, 1993). The age of the event is comparable to the 334,5 Ma obtained by Maluski et al. (1993) from the same granitoide body.

The third metamorphic event associates with an emplacement of relatively younger muscovite granite body into the ULU sheet. Except of the mentioned informations its alkali fedspar saturated liquidus phase resulted into formation of polymigmatitic aureoles at the contact with migmatites of the previous event. Large monomineral K-feldspar porphyroblasts are charakteristic for this event in polymigmatites.

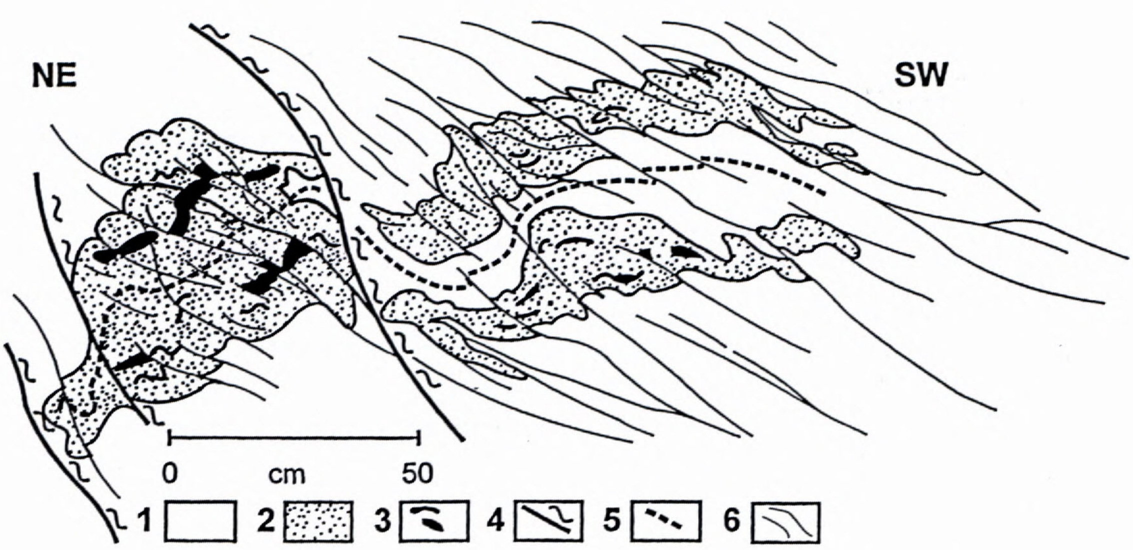

Fig. 3. An example of the Late Variscan - Alpine polystage reworking of the metamorphic suite of the Lodina complex - the Middle Lithotectonic unit of the Variscan structure of the region. Early Alpine (AD_1) isoclinal folding of the Late Variscan secretional quartz lenses and succesive (AD_2) refolding of the E-W folds into regionally penetrative NW-SE fold structures, finally sheared by axial plane cleavage as a consequence of a reverse thrust kinematics of regional shear zones of the Margecany type. The post - Paleogene sinistral shearing reactivation of the zones has produced a mullions formation within the closures of the interfered fold sets (NE part of the figure). 1-diaphtoritised gneisses, 2- secretional quartz, 3-gneisses inclusions within the quartz, 4-axial plane of the Paleo-Alpine fold, 5-dislocations, 6-axial plane cleavage of the NW-SE fold set.

The fourth Variscan event dated to 330-312 Ma (Dallmeyer, pers.inf.) - by the way firstly at the WCl realm, is also detectable geologically. Clasts of both ULU and MLU rocks are present in Late Carboniferous formations of the cover sequence of the Čierna hora Mts. (Korikovskij et al., 1989). A high content of secretional quartz boulders within conglomerates of the formation indicates either synkinematic (diaphtoritic) stage of the event or a rapid pre-Late Carboniferous uplift of the basement units. Following Fritz et al. (1992) we suppose that this green-schist facies event terminates the development of the Variscan nappe structure at the Tatric and Veporic domains of the WCl.

The begining of Alpine tectonometamorphic development in the region is only evidenced by 137,5 Ma Ar-Ar dating of white micas from mylonitized granodiorite of the Veporic part of the ULU (i.e. from the Bujanová complex). The analysed sample was taken from the Bujnisko shear zone (Jacko, 1978) of the NW - SE direction and a moderate dip to SW. The zone is one of pendants of the Margecany shear zone of the same spatial position which rhytmically shear either Veporic and adjoinig Gemeric units (Fig. 1a,b,c). Although kinematically diferent reactivation of the zones during Cretaceous, Miocene and even recent periodes was proved (cf. Jacko et al., 1996) a reality of the Maluski's et al. (l. c.) data also could confirm absence of Early Cretaceous cover formation in the region.

According to Plašienka's (1997) the Cretaceous development of the Veporic metamorphic dome started as the conseguence of burial of its basement and cover formations before 150-130 Ma (Tithonian - Hauterivian). The begining of thrusting and cover shortening at the southern margin of the dome ceased in Early Cretaceous (l.c.). Into this period we locate the first Alpine (AD_1) tectonometamorphic event of the region - i.e. E-W recumbent folding of the MLU basement rocks (incl. secretional quartz layers of the last Variscan event, Fig. 3) and its cover sequence. The formation of subhorizontal cleavage set within the units and a synkinematic growth of chlorite and white micas on them belong likely to the final stage of the event. From white micas in structurally analogous cleavage planes of both palynspaticaly and litofacial content very close the Veľký Bok cover sequence of the central part of the WCl Veporicum unit, Nemčok and Kantor (1989) determined by K-Ar method 101 Ma. For those and other reasons we suppose the Valangian-Albian interval as the time limit for AD_1 deformation stage inclusively the Choč nappe thrusting in the region as well.

A penetrative development of structural and metamorphic assemblages of AD_2 deformation stage throughout the units of the region indicate a thermodynamic culmination of its Alpine tectonometamorphic development. Greenschist facies mineral assemblage (cf. previous chapters) synkinematically growing within NW-SE folds of diaphtoritised MLU (i.e. the Lodina complex) rocks represents thermal climax in this ductilised environment due to overloading by the paleo-Alpine nappe sheets. Anchizonally metamorphosed formations of the Choč nappe are also included into the folds.

The termination of the AD_2 event represents a reverse thrust shortening in the shear zones of Margecany type. The zones penetratively split the NW-SE fold structure of the units into SE vergent monoclinal sheets. Mylonites of the units (incl. cover and Choč nappe formations) occur among clasts of basal (i.e. Eocene) conglomeates of the Intra-Carpathian Paleogene sequence. According to 84-88

Ma cumulation of Ar-Ar geochronological ages of either analogous shear zones or Veporic cover formations of the northern part of the central Veporic zone (Dallmeyer et al., 1993, 1995) we suppose the Late-Coniacian-Early–Campanian reverse thrust activity in the zones of the region.

The third - the Upper Cretaceous extensional AD_3 deformation stage is marked by hydrothermal mineralization filling of the mentioned shear zone structures and by postkinematic growth of Q+Mu+Bi±Ab±Chl paragenese in some silicified parts of those structures. This age also corresponds to temperatures of ore solutions in the neighboring Gemeric unit (150-300^0 Rojkovič in Cambel - Jarkovskij et al.,1985) and testify the formation of hydrothermal veins of the region before its Late - Campanian uplift into cca. 19 km depth as results from 73 Ma FT age of zircon from Čierna hora Mts. granodiorite (Kováč et al., 1994).

Duplexes of Intracarpathian Paleogene formations within paleostress - analyse verified mainly sinistral wrench zones (cf. Jacko et al., 1996) reveal either an intensive post-Paleogene reactivation or formation new NW-SE shear zones in the units of the region. Their SW steeply dipping fault and cleavage planes lead to broad homogenization of the final structure of the region - as is also seen in the upper part of recently shot deep seismic profile G (Vozár et al., 1995). At the ductilely different media of the MLU-the Lodina complex, rocks mullions structures are formed in the AD_2 event refolded more competent secretional quartz layers (Fig.3). This AD_4 event have been likely developed due to eastward escape of the Western Carpthians form the Eastern Alps.

References

Bezák V. 1994: Proposal of the new dividing of the West Carpathians crystalline complexes based on the Hercynian tectonic building reconstruction. Mineralia Slov., 26, 1, 1-6 (in Slovak).

Bezák V., Jacko S., Janák M., Ledru P., Petrík I. & Vozárová A. 1997: Main Hercynian Lithotectonic units of the Western Carpathians. In Geological evolution of the Western Carpathians (Eds. Grecula P., Hovorka D. & Putiš M.), D. Štúr Publ. Bratislava, 1-8 (in print).

Čorná O. & Kamenický L. 1976: Ein Beitrag zur Stratigraphie des Kritallinikums der Westkarpaten auf Grund der Palynologie. Geol. Zbor. Geol. carpath., 27, 1, 117-132.

Dallmeyer R.D., Neubauer F. & Putiš M. 1993: $^{40}Ar/^{39}Ar$ mineral age controls for the Pre-Alpine and Alpine tectonic evolution of nappe complexes in the Western Carpathians. In: Pitoňák P. & Spišiak J. (Eds.): Pre-Alpine events in the Western Carpathians Realm, 11-20.

Dallmeyer R. D., Neubauer F., Handler R., Fritz H., Mueller V., Pana D.& Putiš M. 1995: Tectonothermal evolution of the internal Alps and Carpathians: Evidence from $^{40}Ar/^{39}Ar$ mineral and whole rock data. Eclogae geol. Helv. 89, 203-227.

Fritz H., Neubauer F., Janák M. & Putiš M. 1992: Variscan mid-crustal thrusting in the Carpathians. Part II: Kinematics and fabric evolution of the Western Tara basement. Terra Nova abstr. Suppl. 24, 24

Hovorka D., Méres Š & Ivan P. 1993: Geodynamic setting of the main pre-Alpine basement complexes: The Western Carpathians. Geol. Carpathica 44, 4, 258.

Jablonská J. 1993: Charakterization of zircons from granitoid rocks of the Čierna hora Mts. (Western Carpathians). Mineralia Slov., 25, 3, 157-171 (in Slovak).

Jacko S. 1978: Lithological - stuctural charakteristics of the central part of the Čierna hora Mts. Západ. Karpaty, Sér. Geol. 3, 59-80. (in Slovak).

Jacko S., Korikovskij S., & Boronichin A.V. 1990: Equilibrium assemblages of gneisses and amphibolite s of the Bujanová complex (Čierna hora Mts.), Eastern Slovakia. Mineralia Slov., 22, 3, 231-239. (in Slovak).

Jacko S., Baláž B. 1993: New knowledge about the Čierna hora Mts. metallogenese (Western Carpathians). Mineralia Slov., 25, 232-326. (in Slovak).

Jacko S., Sasvari T., Zacharov M., Schmidt R. & Vozár J. 1996: Contrasting styles of Alpine deformations at the eastern part of the Veporicum and Gemericum units, Western Carpathians, Slovak Geol. Magazine, 2, 150-164.

Jacko S. Vozár J. & Polák M. 1997: Tectonics. In Explanations to geological map of the Branisko and Čierna hora Mts. 1:50 000 (Ed. Polák M.). D. Štúr Publ., Bratislava, 124-148.

Jacko S. Hók J. & Madaras J. 1997: Pre- and syn-granitoid deformations of the Western Carpthians metamorphic complexes. In Geological evolution of the Western Carpathians (Eds. Grecula P. Hovorka D. and Putiš M.) D. Štúr Publ., Bratislava, 1-14 (in print).

Janák M., Bezák V., Broska I., Fritz H., Kahan Š., Kohút M., Neubauer F., O'Brien P.J., Onstott T., Reichvalder P. and Uher P. 1993: Deformation, metamorphism an granitoid magmatism in the Tatry Mts. (Central West. Carpathians, Tatric unit.): records of Variscan and Alpine orogeny. In: Pitoňák and Spišiak, (Eds.): Pre-Alpine events in the West. Carpathians Realm, Excur. Guide, AEWCR, Stará Lesná, 51-61.

Korikovskij S. P., Jacko S., Boronichin V. A. 1989: Alpine anchimetamorphism of Upper Carboniferous sandstones from the sedimentary mantle of the Čierna hora Mts. Crystalline complex (Western Carpathians). Geol. Journ. Geol. carpath. 40, 5, 579-598.

Korikovskij S.P. Jacko S. Boronichin V.A. 1990: Facial conditions of Variscan prograde metamorphism in the Lodina complex of Čierna hora crystalline. Mineralia slov., 22, 225-230.

Korikovskij S. P., Jacko S., Boronichin V.A., Šucha V. 1992: Ilitte-paragonite layer intergrowths from the Gemericum nappe in the SE part of the Čierna hora Mts. Veporicum (Western Carpathians). Geo. Journ., Geol. carpath., 43, 1, 49-55.

Kováč M., Kráľ J., Márton E., Plašienka D., & Uher P. 1994: Alpine uplift history of the Central Western Carpathians: geochronological, paleomagnetic sedimentary and strucural data. Geol. Carpath., 45, 83-96.

Maluski H., Rajlich P. and Matte Ph. 1993: $^{40}Ar/^{39}Ar$ dating of the Inner Carpathians Variscan basement and Alpine mylonitic overprinting. Tectonophysic, 223, 313-337.

Nemčok M. & Kantor J. 1989: A movement study of selected part of the Veľký Bok unit: Region. geol., Spr. o výsk., 25, GÚDŠ, Bratislava, 75-82.

Plašienka D. 1997: Tectonochronology and paleotectonic model of Jurassic - Cretaceous evolution of the Central Western Carpathians. Manuscript-Habilit. theisis, Faculty of Sciencis, Comenius Univ., Bratislava, 1-188.

Petrík I. Broska I. Uher P. & Kráľ J.: 1993: Evolution of the Variscan granitoid magmatism in the Western Carpathians realm. Geol. Carpath. 44, 4, 265-266.

Rojkovič I. 1985: Paragenesis and succession of ore mineralisation. In the Rudňany ore field (Eds. Cambel B. & Jarkovski J.) VEDA Publ., Bratislava, 183-193.

Vozár J., Tomek C., Vozárová A. & Dvořáková V. 1995: Deep seismic profile G: geological interpretation (Inner Western Carpathians, Slovakia), Contrib. of the 3rd Annual meeting of IGCP Project 356. Plate Tectonic Aspects of Alpine Metallogeny in the Carpatho-Balkan Region, 1-3.

Vozárová A. 1993: Pressure-temperature conditions of metamorphism in the northern part of the Branisko crystalline complex. Geol. Carpath. 44, 4, 233-249

Vozárová A. & Faryad S.W. 1997: Petrology of Branisko Crystalline rock Complex. CBGA - Commision on Metamorphism Meeting. Budapest 31-26.