SLOVAK GEOLOGICAL MAGAZINE

Extension tectonics and exhumation of crystalline basement of the Veporicum unit (Central Western Carpathians)

JÁN MADARÁS[1], JOZEF HÓK[1], PAVOL SIMAN[1], VLADIMÍR BEZÁK[1], PATRICK LEDRU[2] & ONDREJ LEXA[3]

[1] Geological survey of Slovak republic, Mlynská dol. 1, 817 04 Bratislava, Slovakia
[2] BRGM, BP 6009, 45060, Orléans, France
[3] Charles University, Faculty of Natural Sciences, Department of Petrology, Albertov 6, 128 43 Praha 2, Czech republic

Abstract: Pre-Alpine crystalline units in the central part of the Western Carpathian range (Slovenské rudohorie Mts.) represents the domain of intensive Alpine overprinting. The Hercynian structural elements are preserved only in relics and they have been incorporated into the Alpine structural pattern. The Hercynian collisional structures - stacking of lithotectonic units - is a result of the Meso Hercynian tectonic stage. In the Late Hercynian evolutional stage the collision in the external zones was finished and crustal extension took place in more internal zones.

The intensive paleo-Alpine deformation had two main stages: thrusting in transpression regime and subsequent extensional unroofing.

After paleo-Alpine and neo-Alpine crustal thickening, inversion tectonic regime took place and exhumation of the crystalline basement followed.

Key words: Central Western Carpathians, Veporicum unit, tectonic stages, thrusting, extensional unroofing.

Introduction

The effects of late orogenic extension are now well identified within collision-type orogens such as the Alps or the Variscan belt. The stacking of nappes resulting from the major lithospheric collision stage led to an unstable thickened crust which tended to re-equilibrate by means of erosion and extensional tectonics developed during vertical uplift and lateral expansion. Thus, the lithosphere accommodated both strain and displacement during collision and extension through its mechanical and thermal behaviour.

The geological evolution of the Veporicum unit is particularly interesting in this framework. The old orogenic crust, mainly composed of quartzo-feldspathic units, has been progressively exhumed, covered by detrital sequences, involved in collision and then re-exhumed.

The purpose of this study is to characterise the tectonic evolution of the Veporicum unit according to the strain partitioning within both the basement and cover sequence. Presented structures and metamorphism within this Alpine lithospheric slab show that the finite strain is mainly related to an Alpine major extensional tectonics. The existence of a possible Late Hercynian extensional tectonics, prior to Alpine collision and extension, is discussed in relation to several geological constrains.

Geological framework

The Veporicum unit - one of the Alpine-formed units of the Western Carpathians - consists of crystalline rocks (basement) and an Upper Paleozoic - Mesozoic cover. Complicated inner structure of the Veporicum unit may be explained by the combined activity of several tectonic stages - pre-Alpine, paleo- and neo-Alpine.

The structure of the basement is heterogeneous and three basic types of complexes are distinguished here :
- high-grade metamorphic rocks of unknown age (Late Proterozoic? - Lower Paleozoic), mainly diaphtoresed;
- low-grade metamorphites of Lower Paleozoic age;
- Variscan granitoid complexes usually in overthrust position on metamorphic complexes and often strongly deformed - as much as to orthogneisses.

Structures - finite strain and kinematics

Structural observations are based on the lithotectonic succession; structural data relate mainly to gneissic - migmatitic and granitic Variscan basement and the Permotriassic sedimentary cover.

Three types of linear structures have been identified in the basement. The first is restricted to highly metamorphosed rocks and the so-called hybridic complex (migmatites; deformed, hybridic granitoids). The second one is mostly visible in deep parts of granitic bodies, but also in the hybridic complex. The third type affects upper parts of granitic bodies near the discordance with the Permotriassic cover.

1.The oldest structural data were found in the relics of high-metamorphosed rocks (such as para- and ortho-

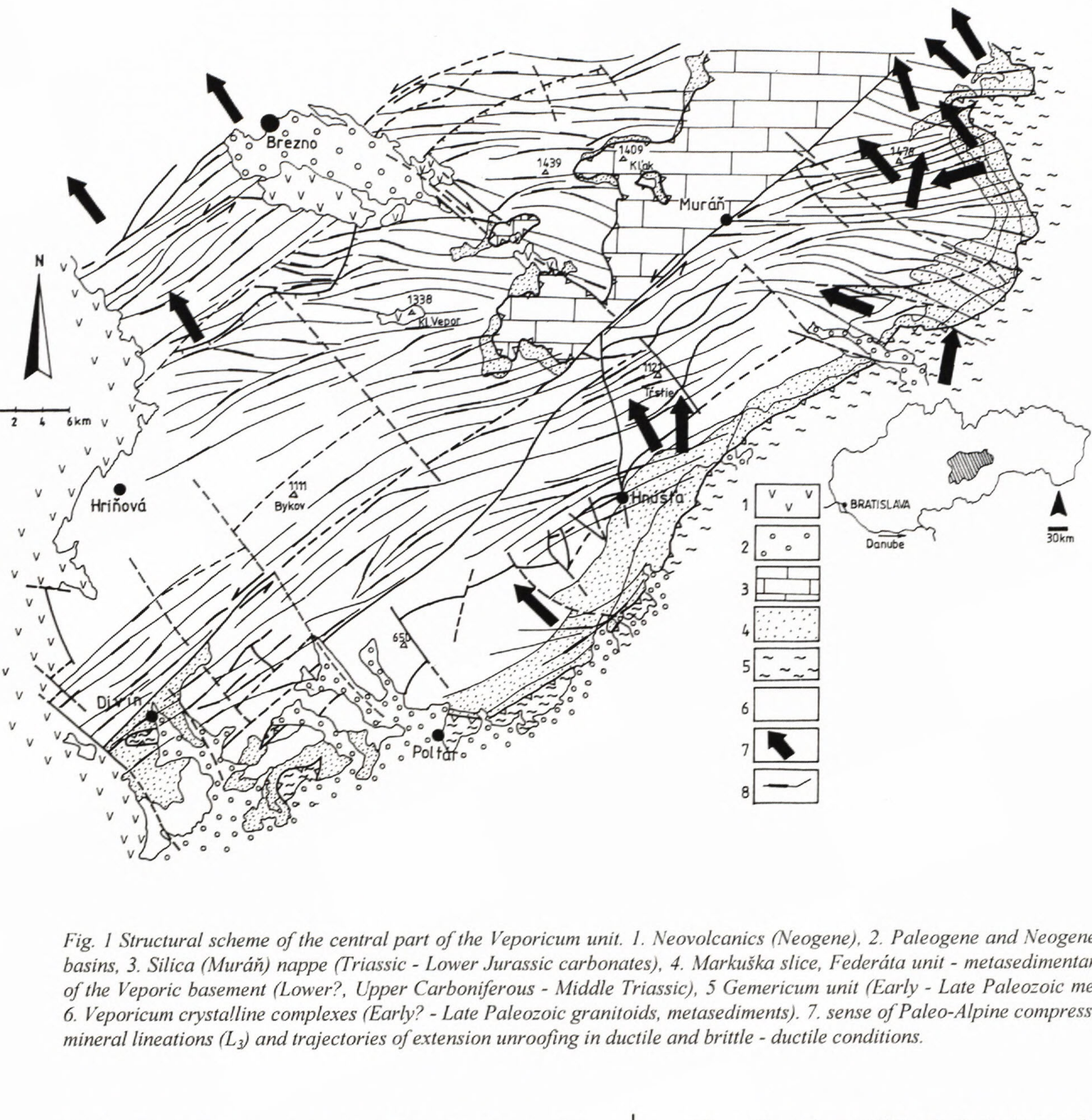

Fig. 1 Structural scheme of the central part of the Veporicum unit. 1. Neovolcanics (Neogene), 2. Paleogene and Neogene sedimentary basins, 3. Silica (Muráň) nappe (Triassic - Lower Jurassic carbonates), 4. Markuška slice, Federáta unit - metasedimentary cover units of the Veporic basement (Lower?, Upper Carboniferous - Middle Triassic), 5 Gemericum unit (Early - Late Paleozoic metasediments), 6. Veporicum crystalline complexes (Early? - Late Paleozoic granitoids, metasediments). 7. sense of Paleo-Alpine compression, 8. Alpine mineral lineations (L_3) and trajectories of extension unroofing in ductile and brittle - ductile conditions.

gneiss, layered migmatites, or hybridic granitoids) interpreted as host rocks of Hercynian granitoids. They occur in a narrow belt beneath the Hercynian granitoids, in their southern part.

The P-T definition and evolution of these relics seems to be very difficult due to a strong lower-temperature metamorphic and deformational overprint, which took place in greenschist facies conditions.

Foliation with the general strike of dip to NW (except folded zones) is regarded as the oldest one (in the whole Veporic unit). Re-orientation of migmatitic and metamorphic foliation planes resulted mainly from a syngenetic ductile deformation in high-temperature processes associated with partial melting.

Migmatites also exhibit a typical changeable of course strike and dip of axial planes of folds and B-axes of asymmetric folds, due to continuous high-plasticity conditions during the deformation. The local rotation of the mineral lineation L_1 (from NW-SE to NE-SW) as a later phenomenon indicates a highly inhomogeneous strain.

2. However, the dominant mineral lineation in deepest parts of hybridic complex is L_2 (Late Hercynian age?). While L_1 formed on metamorphic and migmatitic foliation planes, L_2 originated at ductile C-planes. Together with shear bands it reflects extension and normal tectonics and solid-state or lower-temperature processes, respectively. L_2 with NE-SW direction is slightly dipping to the E or/ and W. The B-axes of asymmetric folds are parallel with L_2. In XZ section there were found boudins of

gneissic xenoliths strongly thermally reworked. It indicates the sense of shear - top to the NE, the same as ductile deformed plagioclase porphyroblasts. Ductile shear zones (318^0 / 30^0, 312^0 / 60^0 -sinistral and 20^0 / 40^0, 54^0 / 30^0, 10^0 / 30^0 -dextral) show the same sense of shear (NE). Biotite in L_2 is developed on S-planes, and on C-planes on a lower structural level. General trend of strike is NE-SW to ENE-WSW. There were observed lineations with biotite (partly rotated) in ductile shear zones.

The main complex of Variscan granitoids is developed on the hanging-wall of the migmatites and hybridic granitoid rocks. The Veporic granitoids are characterised as a complex of several different granitic bodies (porphyric, older S-type granite to granodiorite; isometric, younger I-type granodiorite to tonalite) with different Hercynian age (PETRÍK et al., 1994).
All varieties are more or less affected by strong solid-state deformation. Magmatic foliation is steeply dipping on the contact with the basement complex, however, in the uppermost parts of the present erosion base it is sub-horizontal. This trend is evident mainly in coarse-grained porphyric granites in the central part of the Vepor pluton. Magmatic foliation is sub-horizontal, parallel with mylonitic foliation, with a flat dip to NW or N.

Mineral lineations documents decreasing P-T conditions towards the top wall. Magmatic *lineation* L_2 is defined by biotite in the deepest parts of the granitic body, further on biotite occurs in stretching lineation and on the top the stretching lineation is marked by chlorite. All types are parallel. They formed at different levels in ductile (or post-magmatic) conditions.

3. Alpine stretching lineation L_3 (Fig. 1) is defined by elongated quartz; chlorite; sericite, occasionally biotite and a marked E-W trend with the sense of dip to the E. It is developed especially near the discordance with the cover, partly on C-planes and normal mylonite zones, such as brittle joint-like striae. Lineation is frequently rotated and it is a problem to distinguish it from L_2, because L_3 is defined by the same minerals as L_2 (with biotite, too). L_3 documents continual brittle/ductile extensional deformation with transition to transtensional regime with strike-slips. L_3 on the highest structural levels has the character of brittle striae on joint planes, brittle mylonite zones, locally with hydrothermal alteration. There were observed here only stretching grains of quartz, muscovite-phengite, epidote. Mylonitic foliation has a dip to S, SE, opposite to older magmatic and mylonitic foliations (c.f. SIEGL, 1982). In the XZ section, parallel with L_2 and L_3, there were found kinematic shear-sense indicators: brittle-ductile deformed porphyroblasts of K-feldspar, plagioclase; recrystallised tails with newly-formed albite, biotite, quartz; biotite book-shelf sliding; boudins of quartz - albite veins, quartz extensional veins.

Kinematic orientation of striations shows normal tectonic and horizontal wrenching in brittle -ductile conditions.

Folds and duplex structures were found as kinematic indicators of compression in granitoids. They are present in extremely deformed mylonitic zones, which are characterised by different material rheology. Their orientation indicates the sense of shear (nappe transport) to NW (Fig.1).

The feldspar study in two perpendicular cross-sections (XZ a YZ) shows a very small difference in deformation, the position of deformation ellipsoids in the flattening field. It is typical for extension and dome uplift of the crystalline basement (Fig. 1, 2).

Sedimentary cover sequences were the last complex studied. The crystalline basement (mainly granitoids) is discordantly overlain by a Late Paleozoic-Mesozoic (Permomesozoic) cover, which consist of schists, meta-arcoses, quartzites, occasionally acid volcanites, metacar-

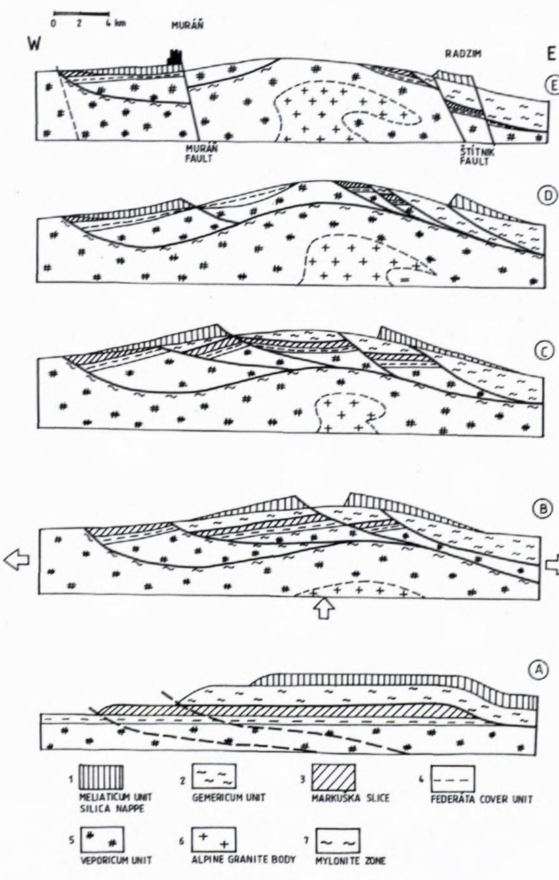

Fig. 2 Model of the Alpine extension unroofing of the central part of the Veporicum unit, West Carpathians range. A.) situation after Paleo-Alpine compression stage - Upper Jurassic - Lower Cretaceous, B.) start of extension stage - Middle Cretaceous, C.), D.) continual extension, formation of listric faults and gravitational movements of nappes - Upper Cretaceous-Tertiary, E.) present time situation. The horizontal scale is real, vertical scale is variabil.

bonates. There is a possibility for age correlation of the Permomesozoic sediments with the crystalline basement. Here there was observed only the third type of linear structures - stretching lineation L_3 and also the youngest striations. Clastic and carbonatic sediments were affected by ductile, brittle/ductile and brittle deformation. Their structural and tectonic development is well-known (PLAŠIENKA,1984;1993; PLAŠIENKA et al.,1989; HÓK et al.,1993).

Conclusions

Pre-Alpine crystalline units in the central part of the Western Carpathian range (Slovenské rudohorie Mts.) represents the domain of intensive Alpine overprinting. The Variscan structural elements are preserved only in relics and they have been incorporated into the Alpine structural pattern. The Variscan collisional structures - stacking of lithotectonic units - is a result of the Meso Hercynian tectonic stage. In the Late Hercynian evolutional stage the collision in the external zones was finished and crustal extension took place in more internal zones (BEZÁK, 1991, 1994, PLAŠIENKA et al., 1993).

The intensive paleo-Alpine deformation had two main stages: thrusting in transpression regime and subsequent extensional unroofing (Fig.1,2).

The following tectonic regimes have been determined:

1. Compression and an overthrusting from SE to NW during the Late Kimerian stage of the Alpine orogeny (Late Jurassic to Early Cretaceous). Successively, the earliest stage of Alpine deformation is represented by duplex structures and folds with axial planes dipping to the SE.

2. Subsequent extension, top-to-the E. The second paleo-Alpine deformation is indicated by mineral stretching lineation, sub-parallel with B-axes of folds, by kink folds being product of the extensional tectonic regime, by numerous kinematic indicators, extension veins and by kinematics of normal faults. In the studied area all indicators point to the regime of ductile deformation close to transition to brittle conditions.

3. Transtensional deformation in brittle conditions. In the younger population of fault planes the compressive tensor changes its orientation from NE-SW to NW-SE. The rock mass movement continued in extensional regime, the direction being generally perpendicular to the Gemeric unit thrust (HÓK et al., 1993).

After paleo-Alpine and neo-Alpine crustal thickening, inversion tectonic regime took place and exhumation of the crystalline basement followed.

Extensional unroofing of the central part of the Slovenské rudohorie Mts. was presumably connected with the uplift of the Veporic crystalline unit. The uplift was accommodated by eastward extensional unroofing of the overlying units (Federáta, Markuška cover units, Gemeric unit, Meliata and Silica nappe). The middle Cretaceous age is determined by Ar-Ar, K-Ar, and FT dating - (c.f. KRÁĽ, 1977, BURCHART et al., 1987, MALUSKI et al., 1993, KOVÁČ et al., 1994). In the crystalline basement, the blasto-mylonitization of crystalline complexes and emplacement of the Rochovce granitic body is dated by different methods at 84-94 Ma (DALLMEYER et al., 1993, MALUSKI et al., 1993, HRAŠKO et al., 1995). There are different opinions on the peak P-T conditions reached during paleo-Alpine metamorphic event in the basement and sedimentary cover (low to medium grade c.f. VRÁNA, 1966, 1980, PLAŠIENKA et al., 1989, VOZÁROVÁ, 1990, SASSI & VOZÁROVÁ, 1992). Continuous uplift is documented by FT ages of apatite (53 ± 7 - 89 ± 10 Ma - KRÁĽ, 1977). Due to the extension, gravitational movements are recorded in the basement and Permomesozoic complexes of the Veporic and Gemeric units.

References

BEZÁK V. 1991: Present knowledge of tectonogenesis of Veporicum (West Carpathians). Mineralia slov. (Bratislava), 23, 381-383.

BEZÁK V. 1994: Proposal of the new dividing of the West Carpathians crystalline based on the hercynian tectonic building reconstruction. Mineralia slov. (Bratislava), 26, 1-6. (In Slovak, English summary).

BURCHART J., CAMBEL B. & KRÁĽ J. 1987: Isochron reassessment of K-Ar dating from the West Carpathian crystalline complex. Geol. Zbor. Geol. Carpath. (Bratislava), 38, 2, 131-170.

DALLMEYER, R. D., NEUBAUER F. & PUTIŠ M. 1993b: $^{40}Ar/^{39}Ar$ mineral age controls for the pre-Alpine and Alpine tectonic evolution of nappe complexes in the Western Carpathians. In: PITOŇÁK P. and SPIŠIAK J. (Eds): Pre-Alpine events in the Western Carpathians' realm. Internat. conf. Excursion Guide, Stará Lesná, 13-20.

HÓK J., KOVÁČ P. & MADARÁS J. 1993: Extensional tectonic of the western part of the contact area between Veporicum and Gemericum (Western Carpathians). Mineralia Slov. (Bratislava), 25, 172-176. (In Slovak, English summary).

HRAŠKO Ľ, MICHALKO J., HATÁR, J., HÓK, J., VAASJOKI M., & KOTOV, A. B., 1995: Upper Cretaceous granite in Western Carpathian region. Terra abstracts, Abstract supplement N°.1, Terra nova, vol. 7, 307.

KOVÁČ M., KRÁĽ J., MÁRTON E., PLAŠIENKA D. & UHER P. 1994: Alpine uplift history of the Central Western Carpathians: Geochronological, paleomagnetic, sedimentary and structural data. Geol. Carpath. (Bratislava), 45, 83-96.

KRÁĽ J. 1977: Fission track ages of Apatites from some granitoid rocks in West Carpathians. Geol. Carpath. (Bratislava), 28, 2, 269-276.

MALUSKI H., RAJLICH P., & MATTE PH. 1993: ^{40}Ar - ^{39}Ar dating of the Inner Carpathians Variscan basement and Alpine mylonitic overprinting. Tectonophysics (Amsterdam), 223, 313-337.

PETRIK I., BROSKA I. & UHER P. 1994: Evolution of the Western Carpathian granite magmatism: age, source rock, geotectonic setting and relation to the Variscan structure. Geol. Carpath. (Bratislava), 45,5, 283-291.

PLAŠIENKA D. 1984: Represents the Markuška nappe an interconnecting element between the Veporic and Gemeric units? Mineralia slov. (Bratislava), 16, 187-193. (In Slovak, English abstract).

PLAŠIENKA D. 1993: Structural patttern and partitioning of deformation in the Veporic Foederata cover unit (Central Western Carpathians). In: RAKÚS M. and VOZÁR J. (Eds): Geodynamic model and deep structure of the Western Carpathians. Conf., Symp., Sem., D. Štúr Inst. Geol., (Bratislava), 269-277.

PLAŠIENKA D., JANÁK M., HACURA A. & VRBATOVIČ P. 1989: First illite-crystalinity data from Alpine metamorphosed rocks of the Veporicum, Central West Carpathians. Mineralia Slov. (Bratislava), 21, 43-51. (In Slovak, English summary).

PLAŠIENKA D., BEZÁK V., JANÁK M. & UHER P. 1993: Record of the pre-Alpine orogenic processes in the Western Carpathians: a synopsis. PAEWCR conference, abstracts, Geol. Carpath. (Bratislava), 4,44, 266.

SASSI F. P. & VOZÁROVÁ A. 1992: Pressure character of the Variscan metamorphism in the Gemericum and Veporicum (West Carpathians, Czechoslovakia). Boll. Soc. geol. ital. (Roma), 111, 33-39.

SIEGL, K. 1982: Structure of the Vepor pluton (West Carpathians). Geol. Zbor. Geol. Carpath. (Bratislava), 33, 2, 171-175.

VOZÁROVÁ A. 1990: Development of metamorphism in the Gemeric/Veporic contact zone (Western Carpathians). Geol. Zbor. Geol. carpath., (Bratislava), 41, 475-502.

VRÁNA S. 1966: Alpidische Metamorphose der Granitoide und Foederata - serie im Mittelteil der Veporiden. Sbor. geol. Vied, Záp. Karpaty, 6, 29-84.

VRÁNA S. 1980: Newly - formed Alpine garnets in metagranitoids of the Veporides in relation to the structure of the Cental zone of the West Carpathians. Čas. pro min. a geol. (Praha), 25, 1, 41-54.