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Deformation and p-T conditions estimated in "layered migmatites" from southern part of Veporicum crystalline basement (Western Carpathians; Slovakia)

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Abstract: The relics of high-grade metamorphosed rocks in the SW Veporicum basement (gneisses, migmatites, or "hybridic granitoids") are interpreted as host rocks of the Hercynian granitoids. There are peraluminous rocks occurring here as well lack an Al_2SiO_5 polymorph. Migmatites exhibit syngenetic ductile deformation associated with partial melting. It appears that melting was active during the deformation. According to calculated p-T conditions for the earliest metamorphism we assume 680-730°C at 4-6 kbar and around 550-600°C for the retrograde branch. Next metamorphosis signify calculated p-T conditions from 480-510°C at 3.5-4.5 kbar to 490-540°C at ~8-10 kbar. Si contents (6.46 p.f.u./22 ox.) of coexisting phengite points to higher pressure conditions ~7 kbar.

Key words: Western Carpathians, Veporicum unit, migmatite, petrology, p-T condition.

Introduction

Veporicum consists of a crystalline basement and Upper Paleozoic-Mesozoic cover. The complex inner structure of Veporicum may be explained by the combined activity of several tectonic stages.

The evolution and the definition of the Veporicum basement before the intrusion of granitoids has still not been sufficiently explained, due to the strong Alpine metamorphic overprint in greenschist facies conditions. This contribution focused on the estimation of P,T conditions in the "hybridic", gneisso-migmatitic unit of the Veporicum basement (Fig. 1).

Previous works - a short review

The Veporicum crystalline basement consists of the old orogenic crust, mainly composed of quartzo-feldspathic units, which has been progressively exhumed, covered by detrital sequences, involved in collision and then re-exhumed. The structure of the basement is heterogeneous. Ideas about tectonic setting and pre-metamorphic development were presented by ZOUBEK (1928, 1936), who assumed a uniform Lower Palezoic volcano-sedimentary complex; ZOUBEK & MÁŠKA, KAMENICKÝ (in MAHEĽ et al. 1967) and KAMENICKÝ (1982) distinguished and specified two stratigraphic - tectonic units. The lower unit is a highly metamorphosed, synkinematically migmatised Middle Proterozoic unit. The upper one is low-grade metamorphosed, of Upper Proterozoic age. KLINEC (1966) suggested Alpine nappe structure of the Veporicum. BEZÁK devoted detailed research to the basement (1982, 1988, 1990, 1991,1992). HOVORKA et al. (1992) divided the pre-Alpine complexes of the Western Carpathians into four groups and classified migmatites in two units, according to their origin. Three main Hercynian lithotectonic units were discerned according to BEZÁK (1994).

The Lower Unit occurs mainly in the southern part and it is tectonically superposed by the Middle Unit. The Upper Unit is present in the form of separate tectonic remnants, and it occurs beyond the boundaries of the studied area. Each unit contains yet several particular complexes.

The Lower Unit is built up of metamorphites of the greenschist facies (mica schists, albitic gneisses, chlorite-muscovite schists, amphibolites). Scattered small granitic intrusions are present rarely.

The Middle Unit comprises a broader range of metamorphites, starting from the upper part of the greenschist facies up to the upper part of the amphibolite facies. The age of the above mentioned metamorphites is uncertain, probably Proterozoic - Early Paleozoic. Radiometric data for more exact dating of the Hercynian metamorphism are missing as well.

Granitoids form large bodies with intrusive contacts, surrounded by high grade metamorphites, such as gneisses and migmatites. They originated (were emplaced) in several pulses. According to radiometric data there are three age groups of granitoids - about 350 Ma, 300 Ma, 280-260 Ma (PETRÍK et al., 1993). Thy are often strongly deformed, as much as to orthogneiss.

Geology of the studied area

The relics of high-grade metamorphosed rocks (gneiss, migmatites, or "hybridic granitoids") are interpreted as host rocks of the Hercynian granitoids. They form a narrow belt beneath the Hercynian granitoids in their southern part.

The descriptive definition refers to more-less stromatitic "migmatites", locally tectonised; biotite-schists (metagreywackes) similar to orthogneiss? from localities Liešnica valley, Klenovec, Muránska Zdychava (Fig. 1).

Peraluminous rocks occurring here as well lack an Al_2SiO_5 polymorph, and contain quartz, plagioclase, biotite, muscovite - phengite, garnet, K-feldspar, ± chlorite, rarely hornblende and accessory minerals - monazite, ilmenite, zircon to allanite, magnetite, sphene, apatite.

It is uncertain what was the protolith of these rocks. It seems that they were "active margin" greywackes (intermediate to rich in Qtz) with contents of shale material (or older acid volcanic - magmatic, quartzo-feldspathic rocks by previous study SIMAN, 1995). These experienced several intense metamorphic events with different p-T-t paths.

Petrography and mineral compositon

Plagioclase forms partly retrogressed to granoblastic aggregates of more or less sodic grains filled with sericite ± zoisite. In the most deformed rocks the plagioclase is commonly replaced by albite and/or a sericite filling. There was no zonation observed in plagioclase grains. However, plagioclase adjacent to a Ca-rich hem of garnet from Klenovec indicates a slight decrease in the anorthite component on the contact with garnet. This phenomena could be interpreted as a relic of normal zoning of plagioclase or it could indicate a reaction with garnet during the "compressional event"?.

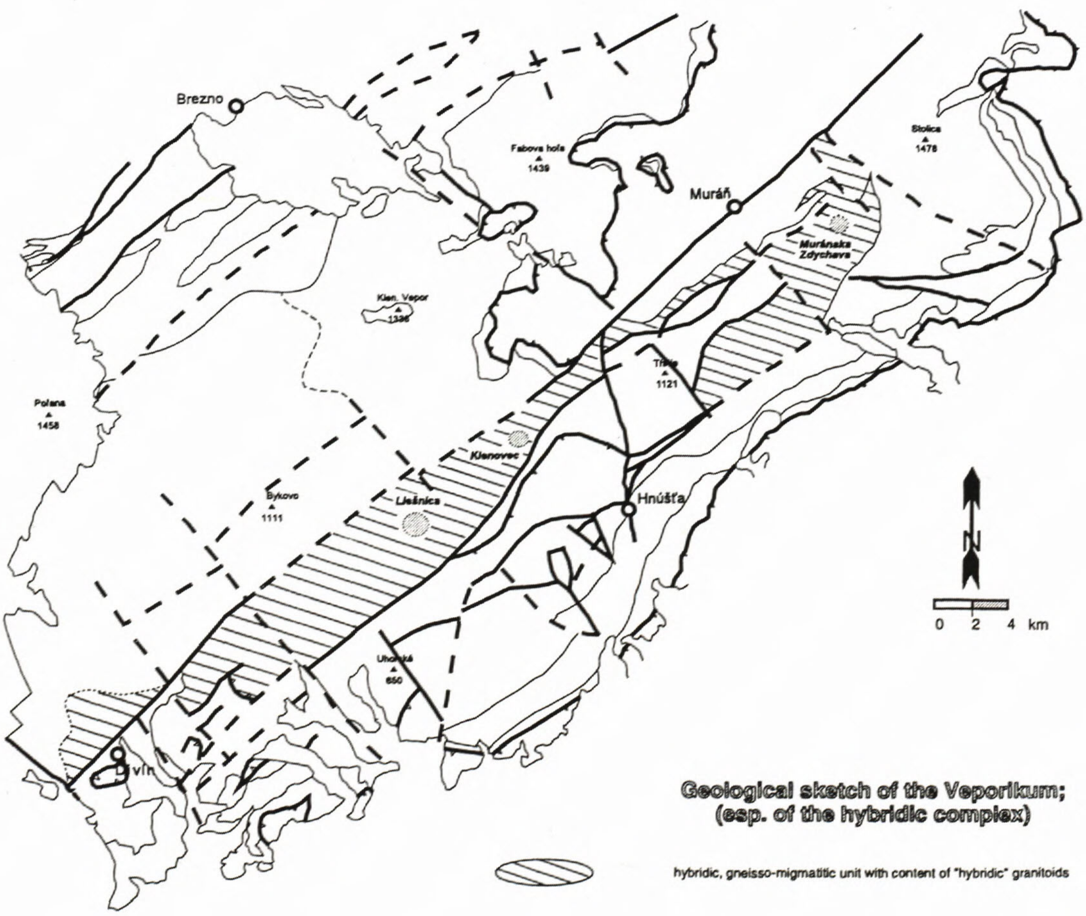

Fig. 1 Geological sketch-map of the "hybridic complex" of the Veporikum (shaded regions represent studied areas)

Quartz often appears as wavy ribbon-like layers or recrystallised granoblastic aggregates and crushed mylonitic grains.

K-feldspar is found as cataclastic, perthitic relics rarely with myrmekitic structures or very small grains in interstitial vacancies between plagioclase, quartz, in Liešnica accompanied on leucogranitoid layers by garnets and muscovites.

White mica is represented by flakes of more or less phengitic composition, with lower content of paragonite and sericite, pseudomorphing plagioclase. It may have increased the pressure of metamorphism, contemporaneously decreasing the temperature at the presence of sufficient amount of fluids. Only some white micas from Klenovec contain up to 20 mol% of paragonite. Muscovite-phengite associated with garnet aggregates shows relativelly higher contents of Si (p.f.u.) from 6.4 to 6.6 /22ox.

Biotite occurs as two or three types, distinguished according to different colours in thin sections, the contents of TiO_2, MgO and FeO/total. $Al^{VI.}$ varies from 0.6 to 1 and Mg/(Mg+Fe) from 0.33 to 0.57, generally, which is relativelly typical of muscovite-bearing amphibolite facies rocks (metapelites, metagreywackes), after GUIDOTTI (1987). However, the biotites from more diferenciated - separated migmatised rocks show a slight shift to lower $Al^{VI.}$ contents, higher Fe contents and they contain about 3 wt % TiO_2. However, the relativelly uniform composition of matrix biotite implies some pervasive Mg-Fe diffusion probably associated with deformation. Clearly different composition has biotite in garnet aggregates; it is more Fe-rich with higher $Al^{VI.}$ contents than biotite elsewhere and contains a very small amount of TiO_2 (0.65-0.98 wt %), generally.

The presence of two *garnet* generations was confirmed by microprobe analyses in some "migmatites". Garnet occurs as small to medium (up to 3 mm) subhedral and brittle crushed porphyroblasts. The older garnet type forms cores of porphyroblasts consisting of almandine-pyrope solid solutions with low contntes of grossularite and spessartine molecules. The younger garnet type forms rims - hems arround older cores and it differs especially by a high-grossularite composition. These hems alone seem to be progressively zoned and sometimes they contain inclusions of clinozoisite-zoisite.

Lack of zoning or few retrograde features in the garnet cores are interpreted as the result of homogenization by cation volume diffusion at more than 600°C, after WOODSWORTH (1977) or of high-grade origin of garnet cores - arround 600-700°C, after AVČENKO (1982).

Garnet from Muránska Zdychava occupies a particular position in the whole unit. It is generally relativelly progade zoned, with increased contents of grossularite molecule.

Two genetic garnet types, with two explanations, have been distinguished in the Veporicum basement rocks by previous observations, by MÉRES & HOVORKA (1991a,b), KORIKOVSKI et al. (1989, 1990), KOVÁČIK (1991, 1993).

Deformation

The general strike of dip of hybridic granitoids and migmatites is to NW. Heterogeneous deformation (with brittle, brittle-ductile and ductile shear mylonitic zones) is associated with the layering, which is folded. Re-orientation of migmatitic and metamorphic foliation planes shows syngenetic ductile deformation associated with partial melting. It appears that melting was active during the deformation (there is melted material along the axial plane of folds, specially in the Liešnica valley).

Migmatites exhibit a typical varying course of strike and dip axial planes of folds and B-axis of asymmetric folds, due to high plasticity conditions during the deformation. The local rotation of the mineral lineation defined by Bt (from NW-SE to NE-SW) indicates highly non-homogeneous strain probably near an early ductile shear zone.

High temperature ductile shear zones and shear bands from Liešnica valley, Klenovec show sinistral movement on meso- and microscale. Ductile deformations of plagioclase probably indicate Hercynian kinematics: top to the NE resp. NE-SW shearing. Dykes of granitoids from Muránska Zdychava are strongly boudinaged and folded except their internal parts. Deformation took place within lithons. Melting conditions were reached in the middle part. High temperature deformation indicates NW-SE movement; later shear bands defined by chlorite indicate Alpine shear to the E.

Geothermometry and geobarometry

Metamorphic temperatures have been estimated from the Fe-Mg exchange reaction between coexisting biotite - garnet, and metamorphic pressure was calculated using garnet - biotite - muscovite - plagioclase callibrations. The first geothermometric and geobarometric results indicate a metamorphic discontinuity across the unit stressed by the presence of regressively zoned cores of garnets with uncertain position of Ca-rich rims (hems).

According to calculated p-T conditions for the earliest metamorphism (equilibration with non-deformed dark brown, TiO_2-rich matrix biotite and garnet cores) we assume 680-730°C at 4-6 kbar and around 550-600°C for the retrograde branch, (Fig. 2).

Garnet from Muránska Zdychava (X-ray mapping) indicates prograde growth zonation with calculated p-T conditions from 480-510°C at 3.5-4.5 kbar to 490-540°C at ~8-10 kbar, (Fig. 2). Si contents (6.46 p.f.u./22 ox.) of coexisting phengite (after Massonne-Schreyer calibration) points to higher pressure conditions ~7 kbar.

Ca (Gross)-rich garnet hems with co-existing new-formed low-Ti biotite, phengite and more or less albitic plagioclase yielded different p-T conditions, approx.. 450-530°C at 7-10 kbar, (Fig. 2).

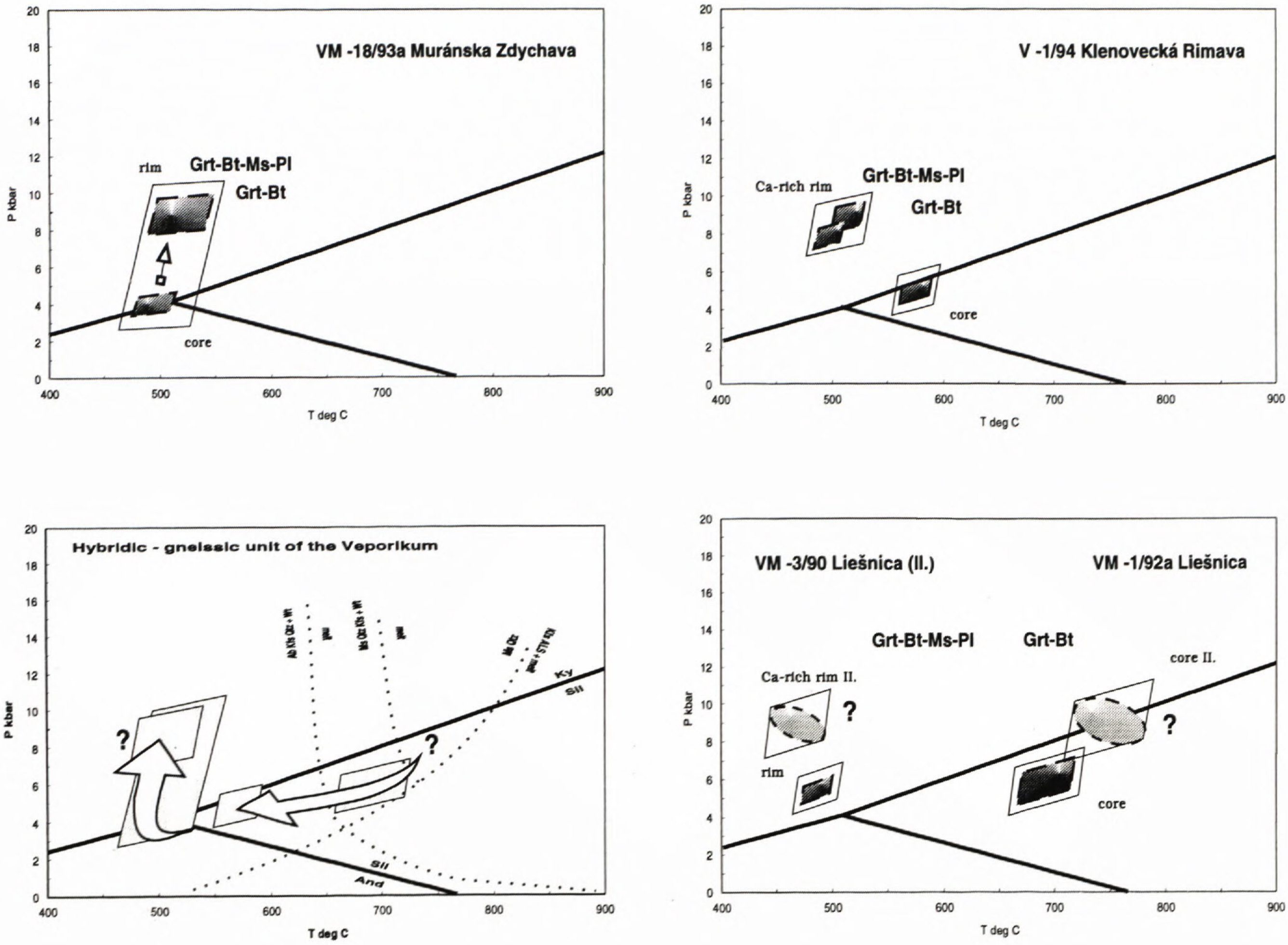

Fig. 2 Calculated p-T conditions of "layered rocks" from southern part of the Veporikum basement (shaded regions represent error boxes for averages of the p, T determinations)

Conclusion

The first results of petrological study and geochemical interpretation suggests complex origin of the "layered migmatites".

The first tectono-metamorphic event reached temperature conditions of the upper part of the amphibolite facies and could be responsible for the Hercynian thickening. The highest p-T conditions probably associated with local partial melting could be also a record of pre-Hercynian history of the basement: migmatites were perhaps products of Cadomian metamorphism (BEZÁK, 1991). There is only indirect evidence of their age: change of metamorphism and different (ductile) deformation pattern in comparison with the Early Paleozoic complexes, tectonic breccias of "layered migmatites" cemented by the Hercynian granitoids. Another next metamorphosis signified by retrograde re-equilibration only. The younger one is characterised by greenschists facies metamorphism, evolving to relatively medium to high pressure conditions.

The main problem for a better understanding of the metamorphic evolution of the Veporicum basement lies in the separation and definition of the intensity and areal extent of the Alpine metamorphic recrystallisation, as both - the Alpine event and the Hercynian retrogression - probably reached very similar conditions. They could be distinguished by the pressure changes.

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