SLOVAK GEOLOGICAL MAGAZINE

Petrogenetic relationship between deformation and alteration on the example of the extension tectonics of the Veporicum crystalline basement (Central Western Carpathians)

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Abstract: The conditions of the deformation in the Veporicum crystalline basement are estimated at middle to upper greenschist facies or the lower part of amphibolite facies; according to these first results, max. T reached approximatelly ~ 450-500°C at P~ 3-4 kbar. The observations from the Permo-Mesozoic cover sediments suggest that deformation occurred in the greenschist facies conditions at a temperature estimated at 350°C (max. 450°C according to crystal plasticity of quartz in the eastern part), or only at anchimetamorphism. Our observations suggest that the major paragenetic transformations reflect probably the strong Alpine overprint. We assume that only relics of higher metamorphosed rocks from the so-called "hybridic complex" in the southern part of the Veporicum basement could bear records of Late - Hercynian events.
Key words: Central Western Carpathians, Veporicum unit, crystalline basement, sedimentary cover, regional metamorphism, metamorphic alteration, paragenetic transformation.

Introduction

The evolution of polyorogenic and polymetamorphic regions is perhaps one of the most discussed uestions in present petrological studies. The Western Carpathians as a part of the extensive Alpine - Carpathian orogenic belt comprise more or less conserved older units. These were, as relic structures, incorporated into the comprehensive framework during the Alpine orogeny.

The Veporicum is an internal part of the central domain of the Western Carpathians and it is an area which consisting of several, differently old tectonicaly approached units.

This short explanation is focused on a very simplified scheme of the metamorphic alterations in the Veporicum crystalline basement during its reworking into the present state.

Localisation of deformation and petrogenetic implications in the basement

Several rocks types occur in the Veporicum crystalline basement, however, this paper discusses the phase relationships in some granitoids and gneisso-migmatitic rocks in the central and southern parts.

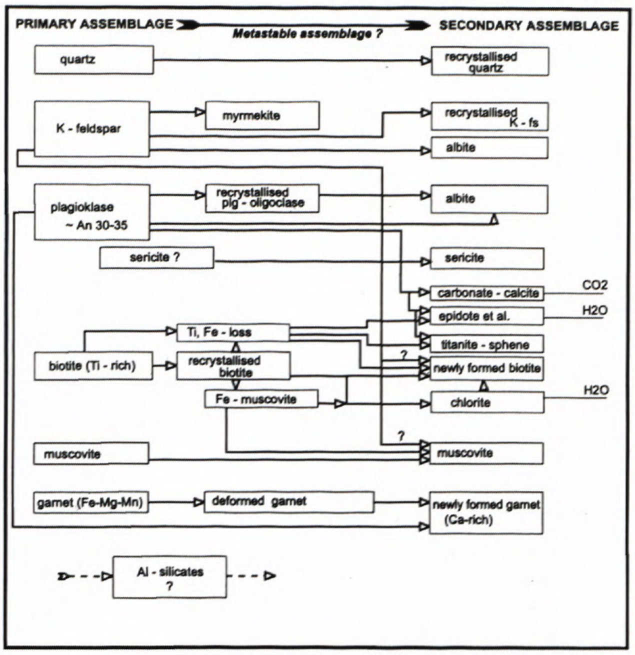
The primary rock-forming mineral assemblages are unstable, recrystallised and replaced due to heterogeneous deformation with grain - size reduction and generally with retrogression. (Fig. 1).

K-feldspar - porphyroblasts in granitoids (partly in "migmatites") are replaced, at first by myrmekitic structures probably associated with strain features. SIMPSON & WINTSCH (1989) showed that myrmekites may form only on the sides of K-feldspar facing the shortening direction. Subsequently they were replaced by perthitic zones associated with partial recrystallisation on the grain boundary. The frequently brittle behaviour of K-feldspars, (Fig. 2.b), without significant recrystallisation and with quartz-albite basic filling of microcracks suggests a low metamorphic grade.

Plagioclase - is mostly completely altered by processes of "reaction softening". This means sericitization, saussuritization and albitization due to sufficient amount of reaction fluids. Only brittle fracturing was observed with quartz filliing of microcracks, (Fig. 2.a,c). In some cases there was preserved the primary zonation of plagioclase with a basic core An ~ 30-35. Plagioclases are rarely recrystallised (in migmatites - metagranitoids) on the grain boundary or only brittle-ductile folded. We assume that retrogression of Plg indicates max. upper greenshist facies.

Quartz - it is characterised by low-temperature cataclastic flow and crystal-plasticity on the grain boundary, or only undulose exstinction. Higher-temperature plasticity - sliding may be considered specially in migmatitic rocks.

(after Kerrich et al., 1980; modified)



(arrows show supposed transport of elements)

Fig. 1 Simplified sketch of alterations during the Hercynian and the Alpine development of the Veporicum crystalline basement (esp. of hybridic complex); the Western Carpathians.

Biotite - 3 generation were observed, especially in migmatitic and granitoid rocks. $Biotite_1$ is represented by relics (L_1?) of dark-brown grains with obvious exsolution of rutile/sagenite, titanite and with content of Ti ~ 2wt % till 3.5wt %. $Biotite_2$ has dark-brown to brown colour without exsolution and with content of Ti ~ up to 2.4 wt% defining the lineation (L_2 and/or L_1). $Biotite_3$ is represented by newly formed, relatively Ti-low (below 1 wt %), greenish grains in microcracks of garnets and plagioclases, (Fig. 2.c,d).

In the main part of the deformed granitoids biotites have been altered - chloritised, baueritised/uralitised. EGGLETON & BANFIELD (1985 in SHELLEY, 1993) suggested a reaction for chloritization in a granite at 340°C.

Muscovite, white mica - they are recrystallised (post-deformational growth was also observe) into brittle-ductile folded porphyroblasts. Muscovite is characterised by phengitic composition, with the lower content of paragonite. It may have increased the pressure of metamorphism, contemporaneously decreasing the temperature, at the presence of a sufficient amount of fluids.

Chlorite - often defines the lineation (L_3) in the deformed granitoids. It originated by retrogression of biotite and as a newly formed radial aggregates in fractures.

Chlorite, sericite and epidote-zoisite group of minerals are the main bearers of deformational strain and retrograde processes in the deformed crystalline basement.

Garnet - has been found especially in "migmatitic" and gneissic rocks, as brittle deformed grains or only relics. Fractured garnet cores, often with slightly regressive zonation, are replaced and enveloped in the newly formed progresive growth-zoned almandine-spessartine garnets with relatively high content of grossularite ~33 to 40 wt %, according to a compilation of previous studies and our own observations.

The cover sequences

The principal mineral assemblages of the sedimentary clastic and carbonatic cover rocks are simply described by the composition: Quartz - Sericite - Plagioclase - K-feldspar ± Muskovite, white mica, Tourmaline, Epidote-Zoisite group.

The bearer of deformation is the weak phase, represented by sericite, but also in some cases by altered and "softened" clasts of plagioclase. The deformational strain was born by quartz only in pure quartzite, where there are few weak phases. Quartz recrystallised on the grain boundary or in brittle-ductile conditions with grain size reduction. K-feldspar - clasts are only fractured.

The conditions of the deformation

The deformation strongly depends on the viscous strength contrast between strong and weak phases, and on the relative amounts of the constituent phases. It is controlled by the quantity of the weak phase.

The conditions of the deformation in the Veporicum crystalline basement are estimated at middle to upper greenschist facies or the lower part of amphibolite facies; according to these first results, max. T reached approximatelly ~ 450-500°C at P~ 3-4 kbar. After evaluation of rheological properties of the crystalline rocks we are inclined to accept the "clast-matrix" type (HANDY, 1990) or in some mylonites the "IWL" equilibrated microstructure (HANDY, 1994).

The observations from the Permo-Mesozoic cover sediments suggest that deformation occurred in the greenschist facies conditions at a temperature estimated at 350°C (max. 450°C according to crystal plasticity of quartz in the eastern part - in the Rejdová area), or only at anchimetamorphism confirmed by illite crystallinity (PLAŠIENKA et al., 1989).

Discussion

The newly formed mineral assemblages in the deformed Veporic granitoids are interpreted as the products of "Alpine dynamometamorphism", after ZOUBEK (1936). The first data on Alpine metamorphism of the South Ve-

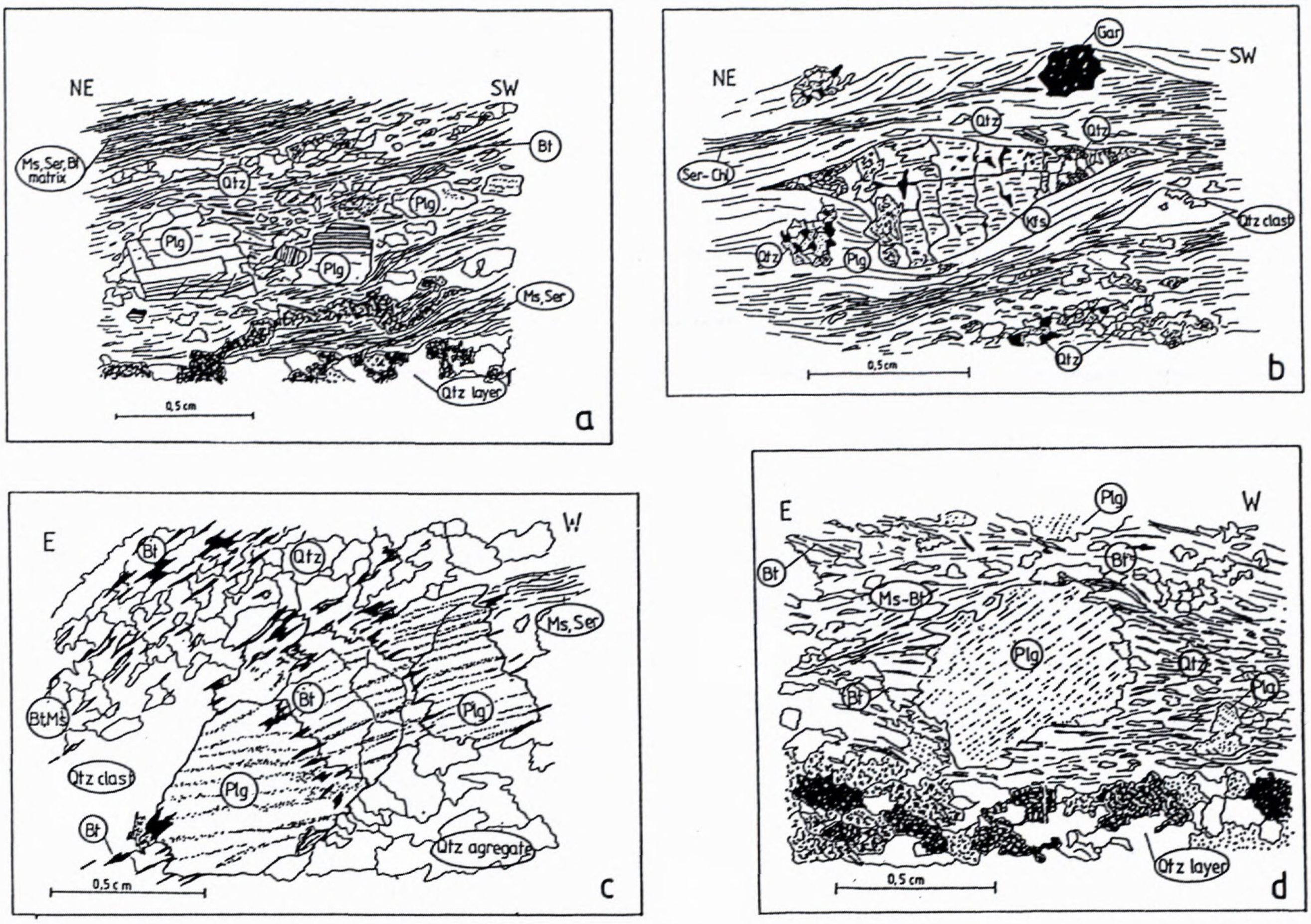


Fig.2 Microdeformation of porphyric granite, blastomylonite. Drawing according to photographs from oriented thin section, XZ cut. A. Veprianska valley, upper part, Klenovec area. Extension deformation. Plg in brittle conditions, gaps with new formed Ab, Qtz, Ser, Bt. Sense of shear to the SW. B. Borový potok, near Klenovec village. Kfs clast, tails form new Qtz. Mylonitic foliation - matrix from Ser, Chl, Qtz. Shear criteria indicate a displacement towards NE. C. Karafová valley, near Muránska Zdychava village. Extension deformation, Plg clast in brittle condition, gaps with new formed Qtz, Bt. Mylonitic foliation - matrix form Qtz, Chl, Ser. Shear criteria show top to the the NE-E.

poric Mesozoic cover reaching the biotite zone of the greenschist facies conditions, on the example of the Foederata Group (Foederata Unit), have been presented by VRÁNA (1966). Using the Kubler index measurements, this should correspond to temperatures of 300-350°C (PLAŠIENKA et al., l.c.). Mineral composition of the Alpine diaphtoritic basement rocks directly underlying the Foederata cover unit (kyanite, chloritoide, biotite and garnet) point to temperatures in excess of 400°C and pressure up to 8 kbar (VRÁNA 1980, MÉRES & HOVORKA 1991).

Recently, b° values of muscovites from the Lower Triassic South Veporic cover rocks determine surprisingly high pressures, up to 12 kbar (MAZZOLI et al. 1992). Generally, the Foederata Unit has been affected by medium to high pressure, low temperature Cretaceous dynamothermal metamorphism typical for collisional orogenic belts. The tectonic overburding during the peak pressure conditions probably did exceed 10-15 km (PLAŠIENKA 1993). Similarly, the South Veporic basement is presumed to have been plunged into the middle crustal level, coresponding to the depth down to 20 km (KOVÁČ et al. 1994). To the contrary, lower to middle pressure conditions 2.5-4 kbar and the temperatures between 350-430°C are estimated to have ocurred during the Alpine overprint in the central part of the South Veporic basement (KOVÁČIK & MALUSKI 1994). KORIKOVSKI et al. (1986) Veporicum determined conditions of regional metamorphism for southern at 400-450°C and 4-4.5 kbar and of contact metamorphism at 450-490°C and 1-1.5 kbar, which are relativelly consistent with data obtained by VOZÁROVÁ & KRIŠTÍN (1985, 1989) and KAMENICKÝ (1977).

Permian sandstones, as a cover of the North Veporic basement only, were anchimetamorphosed during Middle Cretaceous folding events at temperatures of up to 320°C (KORIKOVSKI et al.,1992) and the Foederata group sediments at 250 - 350°C (PLAŠIENKA et al, l.c.). The considerable Alpine recrystallisation, which took place during the Mediterranean phase, is in the case of the Southern Veporic domain attributed to a thick overburden of the Gemeric Unit, whereas the less affected Nothern Veporicum could have only been overlain by the higher superficial nappes (ANDRUSOV, 1968).

The Hercynian regional metamorphism reached temperatures of 500-540°C at the assumed pressure 4.2-7.2 kbar and at 470-360°C as later retrogression for Kraľova Hoľa crystalline complexes and Čierny Balog series, after KRIST et al. (1992). BEZÁK (1991) concluded that the main stage of the Hercynian metamorphism took place at 450-530°C and 4-5 kbar for Early Paleozoic complexes.

Our observations suggest that the major paragenetic transformations reflect probably the strong Alpine overprint. We assume that only relics of higher metamorphosed rocks from the so-called "hybridic complex" in the southern part of the Veporicum basement could bear records of Late - Hercynian events.

References

ANDRUSOV, D. 1968: Grundriss der Tektonik der Nördlichen Karpaten. Vyd. SAV, Bratislava, 188p.

BEZÁK, V. 1991: Metamorphic conditions of the Veporic unit in the Western Carpathians. Geol. Carpathica, 42, 4, 219-222.

HANDY, M.R.1990: The solid-state flow of polymineralic rocks. J. Geophys. Research, 95, B6, 8647-8661.

HANDY, M.R. 1994: Flow laws for rocks containing two non-linear viscous phases: a phenomenological approach. J. Struct. Geol., 16, 3, 287-301.

KAMENICKÝ, J. 1977: Contact metamorphism in the aureole of the Rimavica granite (West Carpathian Mts.). Miner. slovaca, 9, 3, 161-184.

KORIKOVSKI, S. P., JANÁK, M. & BORONIKHIN, V. A. 1986: Geotermometria i izmenenia mineraľnych rovnovesij pri perekristalizacii granat-sľudjannych slancev v kordieritovie rogoviki v oreole rochovsych granitov (Slovackoje Rudogorie, rajon Rochovce-Chyžné). Geol. Carpathica, 37, 5, 607-633. (in Rus., Engl. res.)

KORIKOVSKI, S.P., PUTIŠ, M. & BORONIKHIN, V. A. 1992: Anchimetamorphism of Permian sandstones of the Struženík group in the Nízke Tatry Mts. (Western Carpathians). Geol. carpath., (Bratislava), 43, 2, 97-104.

KRIST, E., KORIKOVSKIJ, S. P., PUTIŠ, M., JANÁK, M. & FARYAD, S. W. 1992: Geology and Petrology of Metamorphic Rocks of the West Carpathian Crystalline Complexes. Comenius Univ. Press, Bratislava, 342 p.

KOVÁČ, M.,, KRÁL, J., MÁRTON, E., PLAŠIENKA, D. & UHER, P. 1994: Alpine uplift history of the Central Western Carpathians:geochronological, paleomagnetic, sedimentary and structural data. Geol. Carpathica, 45, 2, 83-96.

KOVÁČIK, M. & MALUSKI, H. 1994: Alpine reactivation of the Eastern Veporic basement metamorphites (Western Carpathians). Romanian J. Tect. and Region. Geol., Special Abstract volume 75, Suppl. 1, ALCAPA II. - Geological evolution of the Alps-Carpathian-Panonian system, 27-28.

MÉRES, Š. & HOVORKA, D. 1991: Alpine metamorphic recrystallization of the pre-Carboniferous metapelites of the Kohút crystalline complex (the Western Carpathians). Mineralia slov., 23, 5-6, 435-442.

MAZZOLI, C., SASSI, R. & VOZÁROVÁ, A. 1992: The pressure character of the Alpine metamorphism in the Central and Inner Western Carpathians (Czecho-Slovakia). In VOZÁR J. (ed): The Paleozoic geodynamic domains - Western Carpathians, Eastern Alps, Dinarides. D.Štúr Inst. of Geol., Bratislava, 109-117.

PLAŠIENKA, D., JANÁK, M., HACURA, A. & VRBATOVIČ, P. 1989: Prvé údaje o kryštalinite illitu z alpínsky metamorfovaných hornín Veporika. Miner. slovaca, 21, 1, 42-51.

PLAŠIENKA, D. 1993: Structural pattern and partitioning of deformation in the Veporic Foederata cover unit (Central Western Carpathians). In: Rakús, M. - Vozár, J. (Eds.): Geodynamic model and deep structure of the Western Carpathians, GÚDŠ, Bratislava, 269-277.

SHELLEY, D. 1993: Igneous and metamorphic rocks under the Microscope. Chapman-Hall publ., London, 445 p.

SIMPSON, C. & WINTSCH, R. P. 1989: Evidence for deformation-induced K-feldspar replacement by myrmekite. J. Metam. Geol., 7, 261-275.

VOZÁROVÁ, A. & KRIŠTÍN, J. 1985: Zmeny v chemickom zložení granátov a biotitov v kontaktnej aureole alpínskych granitoidov v južnej časti Veporika (Západné Karpaty). Záp. Karpaty, Séria Miner., Petrol., Geoch., Metalogen., 10, Bratislava, 199-221. (In Slovak, Engl. res.)

VOZÁROVÁ, A. & KRIŠTÍN, J. 1989: Termodynamické podmienky premeny metasedimentov slatvinského súvrstvia v stykovej zóne gemerika a veporika. Záp. Karpaty, Séria Miner., Petrol., Geoch., Metalogen., 12, Bratislava, 143-175. (In Slovak, Engl. res.)

VRÁNA, S. 1966: Alpidishe metamorphose der Granitoide und der Foederata - serie im Mittelteil der Veporiden. Zbor. geol. vied, Rad Záp. Karpaty, Bratislava, 6, 29-84.

VRÁNA, S. 1980: Newly - formed garnets in metagranitoids of the Veporides in relation to the structure of the Central zone of the West Carpathians. Časopis pro miner. a geol., 25, 1, 41-54.

ZOUBEK, V. 1936: Poznámky o krystaliniku Západních Karpát. Věstník Stát. geol. úst. ČSR, XII., 6, Praha, 207-239. (In Czech)