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Alpine metamorphism of Southern Veporicum - an evolution model and the problem of correlation with the Eastern Alps

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Abstract. Based on stratigraphic records of Mesozoic sequences, the configuration of geological units as well as geochronological and metamorphic data from the metamorphic crystalline complex, an outline of the Cretaceous geodynamic development of the Southern Veporicum domain is proposed. The metamorphic model is based above all on the concept of the intensive fluid circulation at relatively high heat flow derived from depth. The comparison of Cretaceous orogenesis in Southern Veporicum with the Eastern Alps suggests certain relatedness with the s.c. Mittelostalpin, however, the discussion refers to important differences in the tectonometamorphic development of both regions, too.

Key words: Western Carpathians, Southern Veporicum, Alpine regional metamorphism, basement reactivation, retrogression, Cretaceous orogeny, geodynamic model

Introduction

Among the three basic Central Western Carpathian units (i.e. Tatricum, Veporicum and Gemericum sensu BIELY 1989), built besides remnants of the cover Mesozoic of pre-Alpine complexes, the area of Southern Veporicum (Fig. 1) underwent the strongest Alpine metamorphism. The grade of Alpine recrystallisation is apparently connected with the intensive deformation reworking which is, in contrast to other areas, caused by the thrusting of Gemericum on Veporicum (ANDRUSOV 1968, ZOUBEK & SNOPKO 1954 etc.). Alpine tectonometamorphism is basically interpreted in two ways. The "classical" concept considers a more-or-less uniform pre-Senonian, most probably late Turonian collision (ANDRUSOV l.c., BIELY l.c., TOMEK 1993), when all Alpine units in the Central Western Carpathian region were north-vergently stacked. A more recent idea is based on the time sequence of progressively younger highest stratigraphic members of cover and nappe Mesozoic sequences, from S to N (RAKÚS et al. 1989), which extends the beginning of Alpine orogenic contraction to the Upper Jurassic. As a higher than Triassic lithostratigraphic record is missing in Southern Veporicum (STRAKA 1981), Alpine metamorphism is here, in the sense of the latest theory, regarded as the result of a collision related to the closure of the Meliata ocean (KOZUR 1991, HÓK et al. 1993, PLAŠIENKA 1993a) and placed into the Upper Jurassic - Lower Cretaceous time. The latest structural-geodynamic concept of the development of the Southern Veporicum area has been published by PLAŠIENKA (1993) and partly also by KOVÁČ et al. (1994).

Alpine metamorphism - conditions, relations to deformation and age constrains

The Alpine mineral assemblage in metapelites (muscovite, biotite, chlorite, amphibole of tschermakite type, chloritoid, staurolite, plagioclase, kyanite, garnet phases enriched in the grossularite component) has Barrowian character, in spite of the fact that petrostructurally it is usually late-syn- to postkinematic (similarly VRÁNA 1966). The newly formed assemblage overprinted to a various degree the pre-Alpine minerals (well observable e.g. on porphyroblasts of staurolite, plagioclase, micas and garnet - Fig. 1A, B), which, already before retrograde replacement reactions, frequently underwent Alpine deformation (e.g. reactivated foliation, folds, lineation). Alpine regional metamorphism indicate progressive course (evidenced by succession of blastesis and mineral zonality) and reached in average the middle greenschist facies zone (approx. 350-500°C, at 2-4 kb, KOVÁČIK et al. 1996). These conditions are close to the blocking temperatures of the K/Ar system (amphibole 500°C sensu HARRISON 1981), it may be assumed that the obtained data on newly-formed amphiboles more or less reflect the real age of metamorphic blastesis. In general, we connect the metamorphism with increased geothermal gradient (approx. 40-60°C/km).

In the light of recent $^{40}Ar/^{39}Ar$ dating focused on muscovites (blocking T 350±50°C) and newly-formed amphiboles (not rejuvenated pre-Alpine ones) in metamorphites of the basement (KOVÁČIK et al., l.c.) it appears, along with previous data (MALUSKI et al. 1993, DALLMEYER et al. 1993), that a considerable number of $^{40}Ar/^{39}Ar$ spectra is concentrated into a narrow period of about 86-89 Ma (approximately Coniacian). Important

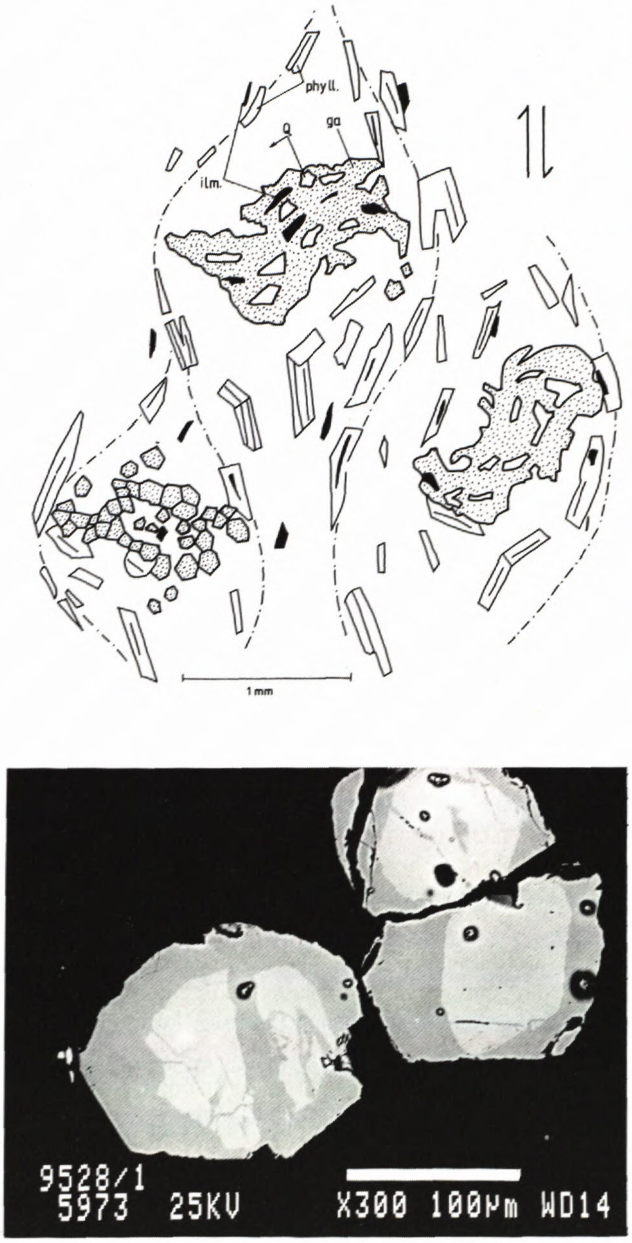

Fig 1 A) Pre-Alpine garnet porhyroblasts are in a shear regime, connected with pressure dissolution (as a corrosion agent there is predominantly quartz), rotated to form assymmetric clasts (right and top). On left, a late stage of decomposition, with disintegration into tiny fragments
B) Catacased relics are along rims and cracks filled with newly-formed garnet enriched in the grossularite component.

manifestations of Alpine metamorphism are asociated with accelerated uplift in the Coniacian-Lower Santonian time. If we extract only the above period to the considerations of Alpine metamorphism, and e.g. 6 km of the overburden rocks would have been denuded during 2-3 Ma, the average rate of uplift would reach then 2 to 3 mm/a. It was probably thermal uplift (sensu lato), accompanied by intensive fluid infiltration connected with metamorphic recrystallisation. The uplift movements, and partly also metamorphic activities, started apparently already earlier, as discussed in the following.

Geodynamic model

As indicated by geochronological data (including K/Ar dating - Kantor 1961, Burchart et al. 1987), it is still an open problem, to which period may the Alpine thermal reworking be more exactly restricted. In spite of the fact that there are more questions than answers, on the basis of the above data we tried to suggest an outline of the chronology of the Cretaceous development in the Southern Veporicum area (Fig. 2). It appears that metamorphic manifestations of Cretaceous orogeny are directly or indirectly associated with two convergent processes: 1) with the collision of Gemericum and Veporicum, with assumed post-deformational effects in the Albian (Fig. 2 B,C); 2) with thermal uplift (about 86-89 Ma) which probably preceded immediately (or was synchronic?) with the thrusting of the s.c. superficial Mesozoic nappes (Fig. 2 E,F). In general it may be assumed that the uplift was not, at least in the early stages, accompanied by thinning of the crust, as it is frequently indicated by the Barrovian character of post-deformation metamorphic assemblages. An uplift regime, even though a little slower, probably took place earlier, as the effect of the collision of Veporicum with Gemericum. It cannot be also excluded that the Southern Veporicum domain was updomed already before the collision event, as evidenced, below the displaced Gemericum elements by the absence of cover Veporicum members younger than Upper Triassic.

After the uplift and thrusting of superficial nappes in the upper part of the crust, there followed the sedimentation of Gossau beds dated maximally as Upper Santonian (Bystrický 1959, Andrusov and Samuel 1983). Probably only from this time, characteristic post-orogenic extensional processes took place (Fig. 2 G), with local temperature perturbantions in the lower/middle parts of the crust (e.g. 81 Ma Rochovce granite, sensu Hraško et al. 1995, or biotite cooling ages). This extensional regime was however no longer connected with penetrative semi-ductile deformations. Stretching lineation along with parallel (to sub-parallel) b-axes of folds, or cleavage planes, developed already during the collision, probably in transpressional regime (Fig. 2 B) and they generally preceded the thermal peak of Alpine metamorphism (Fig. 2 E?). Structures of this type remind of extension parallel with the orogen, developed in many collision orogens, frequently due to oblique convergence (e. g. Ellis 1986).

Metamorphic model

The higher water contents, lower thickness of the lithostatic column, the assumed shorter time range of the

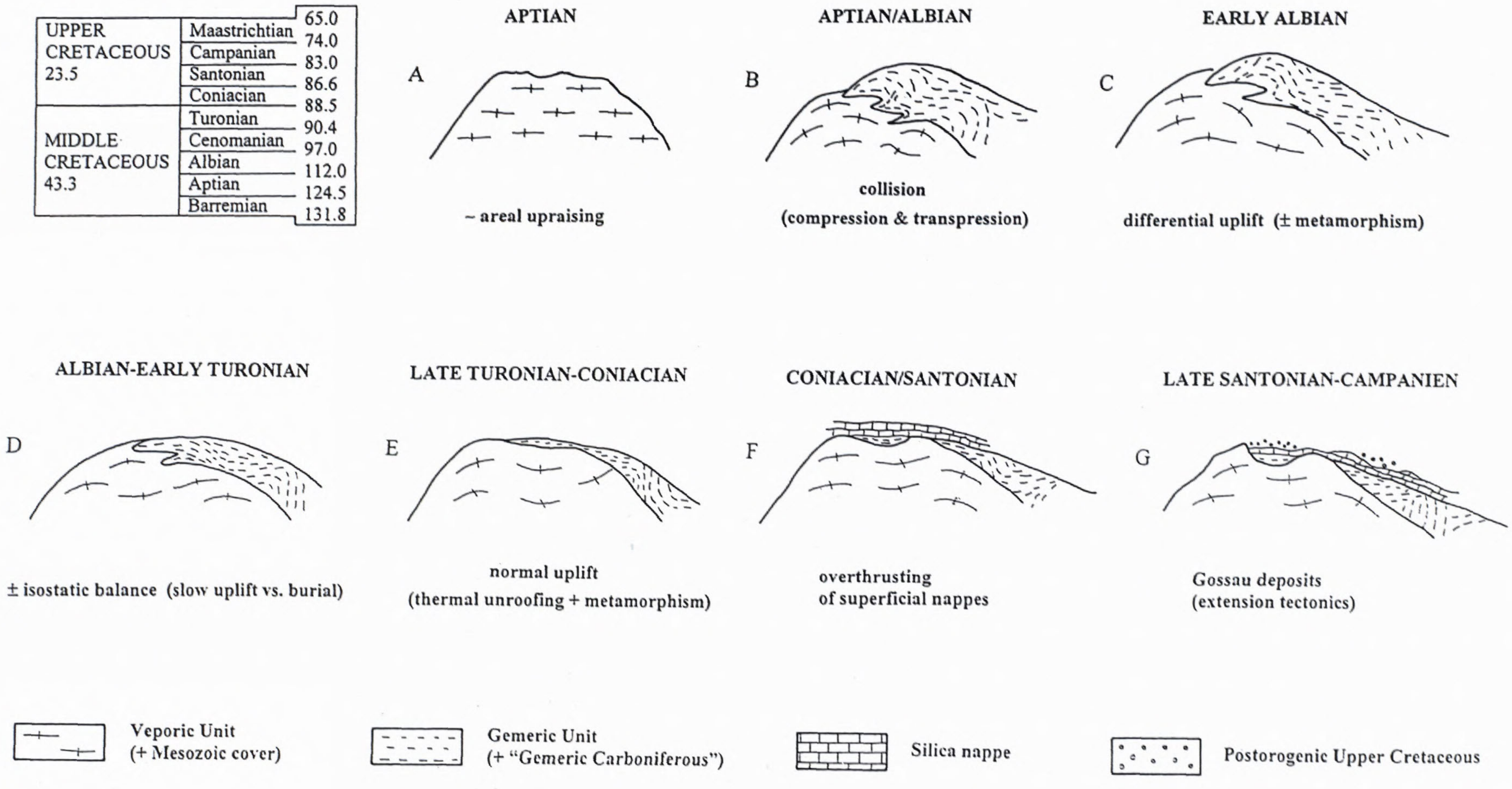

Fig. 2 A geodynamic concept of the Cretaceous evolution of the Southern Veporicum
After assumed morphological elevation (A), there occurred a collision with the Gemericum domain (B) and, due to temperature relaxation, first metamorphic assemblages formed (C). The stratigraphically (with respect to the Northern Veporicum), and partly also geochronologically indistinct period, with possible uplift and/or sedimentation (D) is followed by tectonic denudation with marked manifestations of Alpine matamorphism (E). This "thermal uplift" was subsequently followed by thrusting of the s.c. higher nappes (F). Manifestations of extensional tectonics (completing of F and whole period of G) are in the basement characterised especially by cooling. Geochronological data refer to the chronostratigraphic range of HARLAND *et al. 1989 (see top left).*

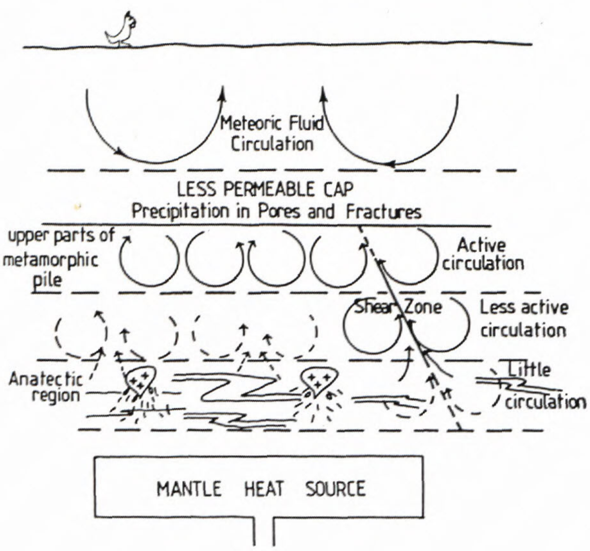

Fig. 3 A schematic model of the fluid-flow system in the regional metamorphic belt
The intensity of circulation increases at higher crustal levels of the crust, where lower-grade metamorphism forms (sensu ETHERIDGE et al. 1983). Similar mechanism may be accepted as a working hypothesis for the explanantion of development of the superimposed Alpine metamorphism in the Southern Veporicum basement

fundamental Alpine thermal reworking etc. could have caused that Alpine progressive metamorphism did not affect clastic members of the cover Permian and Triassic as intensively as retrograde metamorphism affected the basement. It is probable that the principal sources of Alpine metamorphism must be sought in depth reactivation of the basement, where fluid and thermal circulation increase. The generation of increased fluid flow may be also explained by the ascent of hot mantle material into the lower parts of lithosphere. Thinning of mantle lithosphere, which takes place during crustal thickening, contributes to intensive convection flow (ETHERIDGE et al. 1983, ETHERIDGE and LOOSVELD 1990).). Convective removal of the lowermost litosphere due to ascending asthenosphere (sensu PLATT & ENGLAND 1994) could play a significant role, too. As indicated by the model on Fig. 3, different permeability of layers facilitates the fluid circulation, while Upper Permian-Triassic quartzites and quartzitic arkoses could function as a less permeable cap. From this point of view, and because of the dynamic effects of deformations, we consider the thickness of the tectonic overburden of about 5-10 km (especially Gemericum elements) sufficient to create conditions favourable for the Alpine metamorphism of Southern Veporicum.

Correlation aspects

The correlation of Triassic facies of Southern Veporicum with the Eastern Alpine Mittelostalpin (sensu TOLLMAN), as well as the similar configuration of the Mesozoic nappe structure, led to suggesting a common sedimentation basin, proved to have existed to the end of the Jurassic (see e.g. ANDRUSOV 1968, TOLLMAN 1986). The definition of the Mittelostalpin as an independent unit, relatively widely accepted by Austrian geologists, has been questioned by some authors (e.g. CLAR 1973, FRANK 1987), and the unit was interpreted as the lowermost element of the Oberostalpin. (If we would accept this idea, then the assumption of GRECULA (1994) on the approach of Veporicum and Gemericum already in the pre-Alpine period would appear in another light). Regardless whether distinguishing of the Mittelostalpin is justified, the Alpine metamorphism of the crystalline complex in this area generally reached the conditions of the amphibolite facies (e. g. FRANK et al. 1987), i.e. it is somewhat higher than in Southern Veporicum. However, a number of similar petrographic features related to the Alpine recrystallisation (e.g. newly-formed staurolite, kyanite, biotite, garnet rims etc.) indicate a lot of similarity in the development of both regions during the Middle and Upper Cretaceous. Extensional phenomena like semiductile stretching lineation, which is aproximatelly parallel to the b-axis of Alpine folding, probably developed during the process of collisional crustal thickening (RATSCHBACHER et al., 1989) has much in common to that in the Southern Veporicum. The very similar age is supported also by K/Ar and Sr/Rb data, grouped at the time of about 85-90 Ma (e.g. THOENI 1983 in FRANK et al. 1987). The generally lower grade of Alpine recrystallisation of the underlying Unterostalpin, or Tatricum, as well as the dispersed geochronological data from the overlying lower-metamorphic Grauwacken-Zone, or Gemericum, are also evidence in favour of the possibility to correlate these domains even in the Cretaceous time.

Discussion

An important difference in the geodynamic development of both regions may be seen in the findings of Alpine eclogites in the "Mittleostalpin" area. Their possible age is estimated at 95 Ma, however, it is certainly not older than 150 Ma (MILLER 1990, THOENI and JAGOUTZ 1992). The subsequent static Barrovian metamorphism is dated in these rocks at 90 Ma (THOENI - JAGOUTZ l.c.). (Similarly are dated Cretaceous metamorphic events in the Western Alps, where high-temperature metamorphism has been determined at about 110 Ma and peak temperature reworking at 85 Ma, HUNZIGER et al. 1989). Two metamorphic events appear hypothetically also in the Southern Veporicum (see Fig. 2). As high-pressure metamorphism has not been reliably proved from the area of the Cretaceous suture zone between Veporicum and Gemericum, we have no direct evidence that subduction process occurred during this convergence as well. Evidently for this reason, regardless of the marked thermal effects of the later event, we cannot distinguish the characteristic features of both possible phases of Alpine regional metamorphism. The tectonic-thermal relationship between the local contact aureole (e.g. VOZÁROVÁ 1990) of the Upper Cretaceous Rochovce granite (Fig. 2G) and effects of Alpine metamorphism of regional extent (Fig. 2 C-E) is also not quite clear.

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