TECTONOTHERMAL EVOLUTION OF THE AUSTRO–ALPINE – CENTRO–CARPATHIAN MICROPLATE: MICROSTRUCTURAL–P–T–t–d TRENDS – A CORRELATION

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Abstract: The paper reveals characteristic sequence of deformation (D) events of a passive (D1-3) and active (D4-5) margin recognized in reconstructed Eoalpine Austro-Alpine – Centro-Carpathian microplate. It documents common evolution features in fragments of the Apulian plate: collisional underthrusting or continental subduction (D1), lower- to mid-crustal (D2) and upper-crustal (D3) exhumation, transpression-transtension (D4) in northern Apulian margin, lateral extrusion and exhumation (D5).

Key words: tectonothermal, evolution, Austro-Alpine – Centro-Carpathian, microplate

Introduction and paleotectonic-geological setting

The object of the study were some austroalpine structural complexes at the eastern margin of the Eastern Alps, in the Kreuzeck Massif south of the Tauern window, as well as the Veporic and Infratatric structural complexes of the central Western Carpathians.

The reconstructed microstructural-P-T-t-d trends of studied basement fragments represent principal Eo-Alpine (Cretaceous) and Meso-Alpine (latest Cretaceous-Miocene) deformation (**D1-D5**) stages recognized in evolution of the Eo-Alpine Austro-Alpine (**AA**) – Centro-Carpathian (**CC**) microplate (Fig. 1, in a thick frame) derived from the Apulian plate of the African promontory. The AA-CC microplate became part of the composite Tertiary ALCAPA (Alps-Carpathians-Pannonian Basin) microplate.

Here is proposed a correlation of tectonothermal events that occurred in the Apulian orogen internides at the different crustal levels and structural settings, integrating geological, microstructural, P-T, time (t) and deformation-mechanical (d) criteria.

The origin of the lower plate passive continental margin of the AA-CC microplate relates to opening and closing of the middle Triassic - early Jurassic Meliata-Hallstatt basin (Kozur 1991; Putiš 1991a; Plašienka 1991; Tomek 1993; Neubauer 1994; Dallmeyer et al. 1996) that subdivided the Apulian plate into the northern AA-CC and southern pre-Adriatic microplates.

The Alpine overprint represents the whole-crustal rebuilding of the former usually Variscan basement structure. It started with an early-Alpine continental rifting and formation of thinned zones often intruded by acid to basic subalkaline (mostly Permian) or alkaline (mostly Triassic) volcanics, subvolcanics and small granitic or gabbroic intrusions in the AA and CC domains (Dercourt et al. 1990; Bonin 1993, Thöni and Jagoutz 1992; Korikovsky et al. 1995; Uher and Broska 1996; Kotov et al. 1996; Putiš et al. 2000b; Uher et al. 2002) during the early-Tethys evolution.

The AA-CC internides underwent early-Eoalpine collision before ca. 130?-100 Ma that is proven by isotope ages (Thöni and Jagoutz 1992, 1993; Dallmeyer et al. 1996, 1998; Maluski et al. 1993; Kráľ et al. 1996; Kováčik et al. 1997; Putiš et al. 2000a, 2002b). The colliding AA-CC and pre-Adriatic continents were separated by a suture after the closure of the Meliata-Hallstatt basin and subduction of its oceanic crust at ca. 170-150 Ma (Dallmeyer et al. 1996; Faryad and Henjes-Kunst 1997).

Eoalpine P-T-t-d trends of the AA structural complexes

The Middle AA continental eclogites however do not represent the Meliata suture zone (with maximum blueschist-facies HP rocks, Faryad 1997), but suggest a shortening and continental subduction of some thinned AA basement fragments within the passive continental margin of the Meliata-Hallstatt basin (Neubauer 1994; Froitzheim et al. 1996; Dallmeyer et al. 1996; Hoinkes et al. 1999; Putiš et al. 2000a, 2002a, b). The Lower AA unit underwent Early Cretaceous LT/(MT)-MP/(HP) metamorphism too (Korikovsky et al. 1998), while the Upper AA unit escaped from the continental underthrusting zone and was stacked over the thickened continental collisional wedge (Platt 1993) like an orogenic "lid".

The Middle AA Sieggraben structural complex (SSC) underwent Early Cretaceous continental subduction (Putiš et al. 2000a, 2002b) to depth of ca. 50-55 km with the estimated mean temperature of 720 °C at about 15 kbar (D1). Thermal relaxation under increasing temperatures to ca. 770 °C and slightly decreasing pressures resulted in rapid exhumation (D2) recorded by reaction symplectites of clinopyroxene2$_{Jd3-22}$ and plagioclase2 in eclogites and HP amphibolites. The (D2) exhumation was enhanced by the dynamic strain softening of prograde metamorphic omphacite$_{Jd38}$ and zoisite1 into aggregate of minor clinopyroxene2$_{Jd18-31}$ and zoisite2. Plastic deformation of omphacite at high temperatures (750-650 °C) slightly predated plastic deformation of honblende(1) and plagioclase(1) at medium temperatures (650-500 °C) in metabasites. Feldspars and quartz plastically deformed and recrystallized at medium temperature in granitic orthogneisses. All textures reflect micromechanism of dislocation creep. Calcite in marble preferably deformed by mechanical twinning.

Compressional exhumation (D2) along a detachment fault initiated top-to-the SSE extensional unroofing of the eclogitized SSC now overlying the low-grade MP/HP Lower AA structural complexes. A superimposed, top-to-the WSW extensional shearing represents a younger low-temperature exhumation (D3) event that overprints the base of the eclogitic complex and footwall Lower AA Grobgneis and Wechsel structural complexes, finally leading to ultracataclasis and local pseudotachylytization. The estimated conditions point to continental subduction of the studied basement fragment (SSC) at an average geothermal gradient of ca. 13 °C/km (D1). The cooling rate of ca. 40 °C/Ma during the D2 exhumation stage (derived from Zrn U-Pb and Am ^{40}Ar-^{39}Ar ages) implies an exhumation rate of ca. 4-5 km/Ma.

Eo-/Meso-Alpine P-T-t-d trends of the AA structural complexes

The study of *Austro-Alpine (AA) basement complexes of the Kreuzeck Massif* southeast of the Tauern window revealed an association of HP rocks with mylonitoclasites (Putiš et al. 2002a) along an inferred latest-Cretaceous - early-Tertiary lateral strike slip-fault shear zone (D4) crosscut by volcanic dykes (32 Ma, Deutsch 1984) and Miocene ultracataclasites and pseudotachylites. The beginning of D4 stage is poorly constrained by two 61 and 66 Ma ages (K-Ar dating of fine-grained WhM from a mylonite, Waters ex Hoke, 1990).

The HP amphibolites to eclogites (?) and the host kyanite-garnet paragneisses and granitic orthogneisses form tectonic lenses of the AA *Polinik structural complex* along this shear zone. The ductile fabrics in barroisite- and clinopyroxene (high-Na augite)-bearing HP amphibolites to eclogites (?), as well as granitic orthogneisses postdate metamorphic HP fabrics. The estimated conditions of Cretaceous collisional metamorphism (D1) are ca. 530 °C at minimum 11 kbar.

The AA *Strieden structural complex* is overprinted by newly-formed (D1) assemblage of chloritoid, margarite, albite, garnet, at estimated (Cretaceous) T_{max} of ca. 500 °C and 6-7 kbar of P. The rocks show simultaneous micromechanisms of mylonitic (ductile) and cataclastic, or frictional-viscous flow (Handy et al. 1999) in quartz-feldspar- and calcite-dolomite rocks. The measured (plagioclase, quartz, calcite, dolomite) mineral textural patterns are related to (D4) dextral strike slip (Putiš et al. 2002a).

Miocene extensional sliding of the AA structural complex (the Tauern window)

Textural patterns of the footwall Pennine calcite marbles at the eastern edge of the Tauern window (Putiš et al. 2002a) reflect only the first stage of the uplift deformation i.e. subvertical flattening of original metamorphic grains (400-800 μm of size) and the development of dense and narrow e-lamellae (15-30 μm) oriented at the acute angle to S(shape) foliation. Mechanical twinning changed to dynamic recrystallization, producing new grains 15-20 μm in size, excludingly within the ca. 100 μm narrow shear bands (ca. 5 per 1 cm) during the lowest temperatures of the uplift exhumation or top-to-the E extensional sliding (D5) of the AA structural complexes from the Pennine ones.

Eoalpine P-T-t-d trends of the CC (Veporic-Gemeric) structural complexes

The laterally adjacent CC (Veporic-Gemeric) passive continental margin (north of the Meliata nappe suture) shows similar picture with the underthrusted Veporic and overthrusted Gemeric units at ca. 110-95 Ma (isotope ages after Bibikova et al. 1990; Dallmeyer et al. 1996; Maluski et al. 1993; Kráľ et al. 1996; Kováčik et al. 1997).

The *South-Veporic unit* underwent continental collisional underthrusting and metamorphism (D1) in upper greenschist to middle amphibolite facies conditions (mostly 450-550 °C at 7-9 kbar, Vrána 1964; Korikovsky et al. 1989, 1997a; Méres and Hovorka 1991; Putiš 1987, 1989, 1991a, b, 1994; Mazzoli et al. 1992; Putiš et al. 1996, 1997a, b; Kováčik et al. 1997; Plašienka et al. 1999; Lupták et al. 2000; Janák et al. 2001; Koroknai et al. 2001). It was overthrusted by the mostly low-grade Gemeric unit resembling the Upper AA and Southern Alps units.

The *North-Veporic unit*, including the anchimetamorphosed frontal fragments in northern Čierna Hora and Tríbeč Mts., accreted (D3, 85-75 Ma) to exhumed (D2, 95-85 Ma) South-Veporic unit after the Zliechov basin closed and the Krížna nappe was expulsed over the Tatric unit. The newly-formed white mica of this (D3) stage was dated 82 Ma (Dallmeyer et al. 1996). The upper limit of D3 are the zircon FT ages (from 75 Ma in southern Veporicum to 55 Ma in northern Veporicum, Kráľ et al. 1977, 1982; Kováč et al. 1994). The basement-cover complex (fold-and-thrust belt) shows greenschist to anchimetamorphic overprint (Putiš 1987, 1989, 1994; Korikovsky et al. 1997a, b).

Eo-/Meso-Alpine P-T-t-d trends of the CC (Tatric-Infratatric) structural complexes

The *Tatric unit* does not fit to AA part of the Apulian plate, because is unmetamorphosed rooted in front of the Veporic unit and the recent contact along the Čertovica tectonic line is reactivated as a seismoactive fault (Šefara et al. 1998). This fact limits the inferred northern early-Eoalpine Apulian margin in the CC domain roughly to the Čertovica tectonic zone (the northern boundary of the early-Eoalpine tectonometamorphic reactivation). However, the boundary between the thick-skinned (the whole-crustal) and thin-skinned (upper-crustal) tectonics is an intraveporic mid-Cretaceous Pohorelá (sinistral strike-slip) fault dividing also paleotectonically different the South- and North-Veporic units (Putiš 1991a, b, 1992, 1994).

The *Infratatric unit* (in front of rigid Tatric unit) represents a distal allochthon thrusted over and refolded with the Jurassic-Upper Cretaceous sediments of a foreland Humienec succession (Leško et al. 1988) or a peri-Klippen-Belt basin (Putiš 1992), the latter considered by Plašienka et al. (1994) as analogy of oceanic southern Penninicum. Anchimetamorphic overprint of the Infratatricum (Putiš 1986; Plašienka et al. 1993; Korikovsky et al. 1995) and underthrusted sediments reflects the thrusting of the Tatricum over the Infratatricum in mid-late Cretaceous (ca. 80-74 Ma, in the Malé Karpaty and Považský Inovec Mts., Putiš 1991b) and then the Infratatricum (+ Tatricum) over Cretaceous flysches at ca. 46 Ma (anchimetamorphic K-Ar age of an olistolith of Permian? subalkaline basalt in Upper Cretaceous flysch, Dunkl, Frisch, Putiš in prep.).

Conclusions

Eoalpine period of tectonothermal reactivation of a passive margin (D1-D3):

D1 stage: collisional underthrusting (a system of asymmetrical shears) in an orogenic wedge, leading to continental subduction (early-middle Cretaceous, ***130?-100 Ma***).

D2 stage: short-lived thermal relaxation of underthrusted or subducted fragments followed by lower- to middle-crustal exhumation (middle Cretaceous, ***100-90 Ma***) along compression master detachment- and extensional faults.

D3 stage: (middle-) upper-crustal exhumation due to postcollisional collapse (late Cretaceous, ***90-65 Ma***) in system of extension and transpression-transtension thrust-faults; the rooting of Tatric rigid block and accretion of Infratatric distal allochthon to the Tatric unit (80-70 Ma), suggesting the change for an active continental margin.

Mesoalpine period of tectonothermal reactivation of an active margin (D4-D5):

D4 stage: transpressional burial and transtensional exhumation of low-grade and very low-grade basement and sedimentary complexes in the upper-crustal orogenic wedge (late Cretaceous to Oligocene, ***65-35 Ma***).

D5 stage: post-collisional (in relationship to outer externides collision) uplift along the upper crustal lateral extrusion zones and subvertical faults (late Oligocene-Miocene, ***35-15 Ma***) connected with formation of ultracataclasites (and/or pseudotachylites).

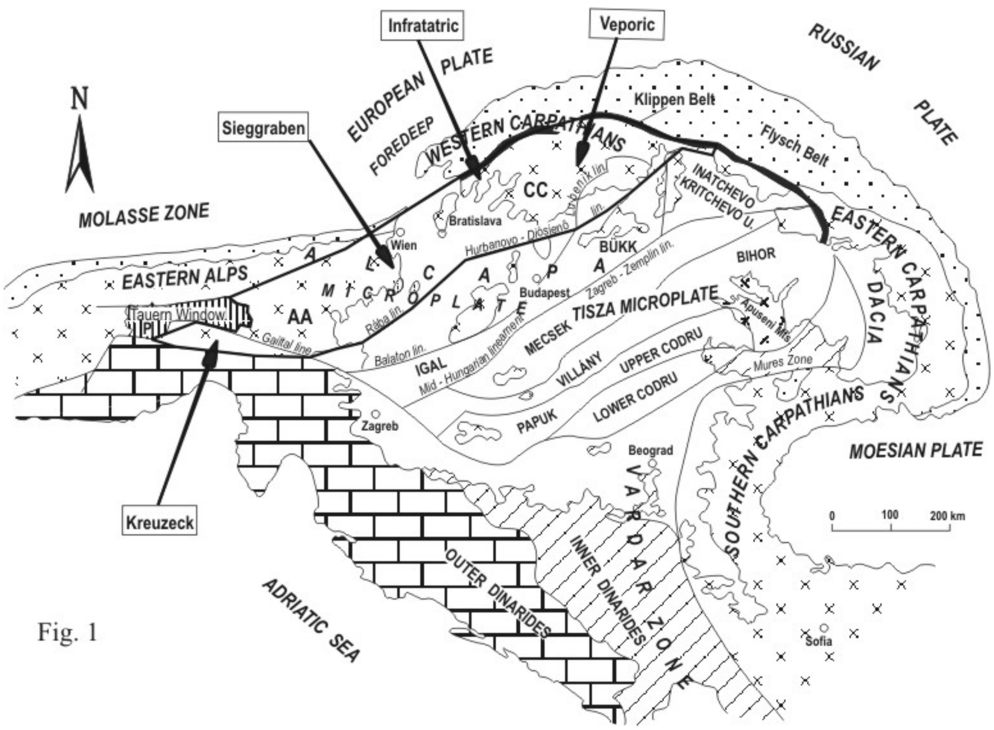

Fig. 1

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