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ALPINE (CRETACEOUS) METAMORPHISM IN THE WESTERN CARPATHIANS: P-T-t PATHS AND EXHUMATION OF THE VEPORIC CORE COMPLEX

Marian Janák, Mike Cosca, Fritz Finger, Dusan Plasienka,
Balazs Koroknai, Branislav Luptak & Peter Horvath

The Central Western Carpathians (CWC) represent a tectonic system that correlates with Austroalpine units extending eastward from the Alps. The pre-Tertiary complexes of the CWC originated during Cretaceous collisional shortening and stacking of the lower plate following Late Jurassic closure of the Meliata ocean, the most intense metamorphism affected the Veporic unit. The tectonometamorphic history of this area was previously interpreted as essentially pre-Alpine, with only minor, greenschist facies Alpine overprint. In contrast, recent results (JANÁK et al., 2001; KOROKNAI et al., in print) emphasized that the Alpine overprint reached amphibolite facies. In this study, new geochronological data on monazite are presented, constraining the Middle Cretaceous time for the peak metamorphism in the Veporic unit, and the *P-T-t* paths are reconstructed.

The Veporic unit comprises pre-Alpine basement (Variscan granites and high-grade metamorphic rocks) overlain by the Upper Palaeozoic–Triassic sedimentary cover. All these rocks show a heterogeneous Alpine overprint related to the development of the metamorphic core complex structure during Cretaceous orogeny. The complex is intruded by Late Cretaceous Rochovce granite.

Three Alpine metamorphic zones are recognized in the central and eastern part of the Veporic unit: (1) chloritoid + chlorite + garnet; (2) garnet + staurolite + chlorite; and (3) staurolite + biotite + kyanite (JANÁK et al., 2001). The isograds separating the metamorphic zones are roughly parallel to the north-east dipping foliation related to extensional updoming along low-angle normal faults. The sequence of metamorphic reactions and their topology in *P-T* space suggests a single metamorphic cycle. Thermobarometric data yield *P-T* conditions from c. 500°C and 7–8 kbar to c. 620 °C and 9–10 kbar (JANÁK et al., 2001). The metamorphic zonation reflects a coherent and continuous metamorphic field gradient from greenschist to middle amphibolite facies, the metamorphic grade increasing with depth.

Chemical Th-U-Pb dating of monazite by means of the electron microprobe has been applied to broadly constrain the peak-PT age of regional metamorphism in the Veporic unit. The results can be taken from the total-Pb vs Th* diagram in Fig. 1. Monazites from three samples were analysed together with a monazite age standard (F-5 Std.; recommended value 341±2 Ma). Monazites from two metapelite samples (V8b from the chloritoid + chlorite + garnet zone and VV4/99 from the staurolite + biotite + kyanite zone) indicate a unique Mid-Cretaceous formation age (weighted averages: 91±25; 92±16 Ma). A mylonitic granite (CL3) contains two generations of monazite, one with an older (c. 370-350 Ma) Variscan age and the second with an Alpine (c. 100-90 Ma) age. Some monazites in sample CL3 have old cores and young rims, the latter being also compositionally distinct (e.g. lower Y, U).

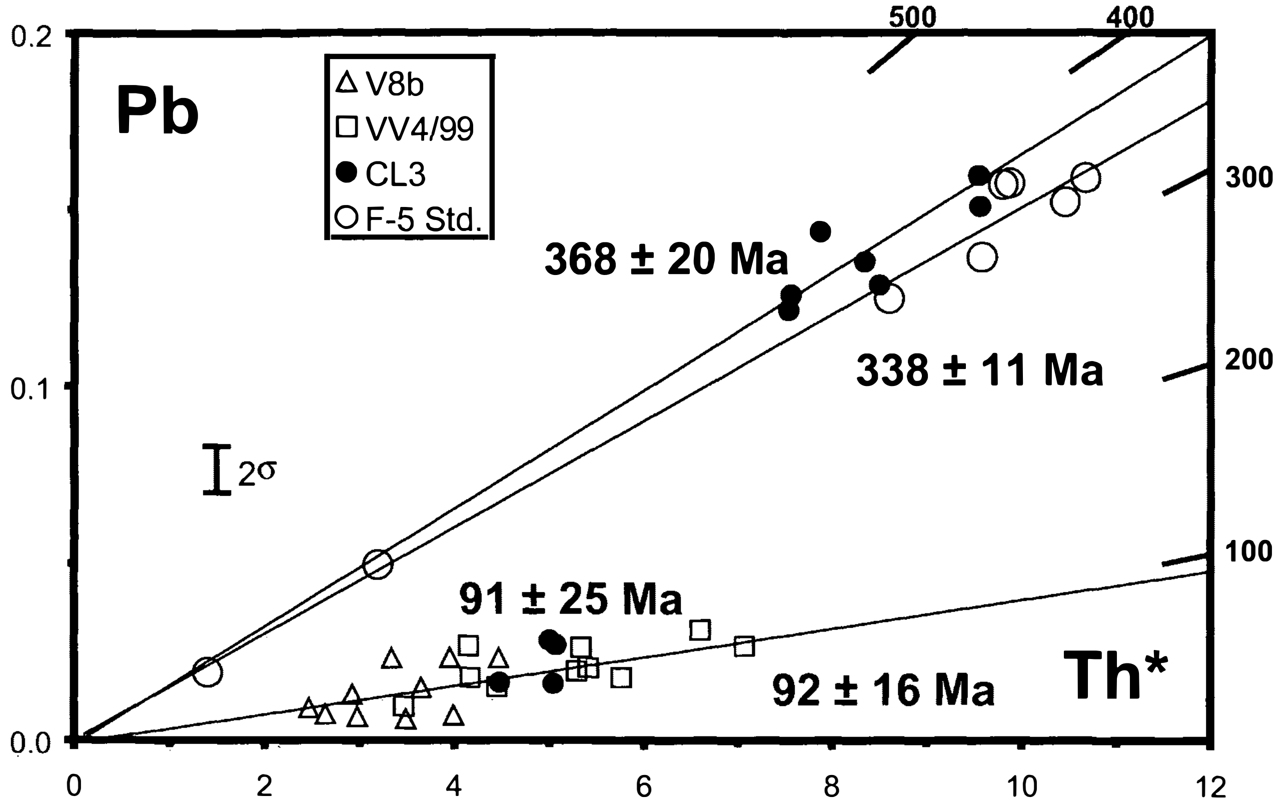

Fig. 1

$^{40}Ar/^{39}Ar$ data obtained by *in situ* UV laser ablation of white micas (JANÁK et al., 2001) constrain the timing of cooling and exhumation in the Late Cretacous. Mean dates are between 77 and 72 Ma, however, individual white mica grains record a range of apparent $^{40}Ar/^{39}Ar$ ages indicating that cooling below the blocking temperature for argon diffusion was not instantaneous. No pre-Alpine dates have been determined, implying that all white micas equilibrated during the Alpine cycle.

The *P-T-t* path followed by individual rocks in the highest-grade (staurolite + biotite + kyanite zone) metapelites is depicted by the trajectory in Fig. 2, crossing dehydration reaction curves and metamorphic field gradient near the metamorphic peak (T_{max}) conditions. This part of the *P-T-t* path was presumably related to post-burial heating as a consequence of thermal relaxation of the geotherm after crustal shortening and thickening. Based on monazite dating we suppose that the peak metamorphic conditions were reached in the Middle Cretaceous time (c. 92 Ma). The retrograde portion of the *P-T-t* path is inferred from the development of (C')-shear planes and partial transposition of porphyroblats oblique to the primary foliation (S) planes. Partial transformation of kyanite to sillimanite in high-strain domains indicates a post-peak decompression and cooling close to the boundary between the kyanite and sillimanite stability fields. Cooling through a temperature of c. 400°C at c. 72 Ma is recorded by the $^{40}Ar/^{39}Ar$ system in the white micas. Early stages of unroofing involving nearly isothermal decompression were probably triggered by erosional denudation, whereas the final stages of exhumation were facilitated by extension along a low-angle normal faults.

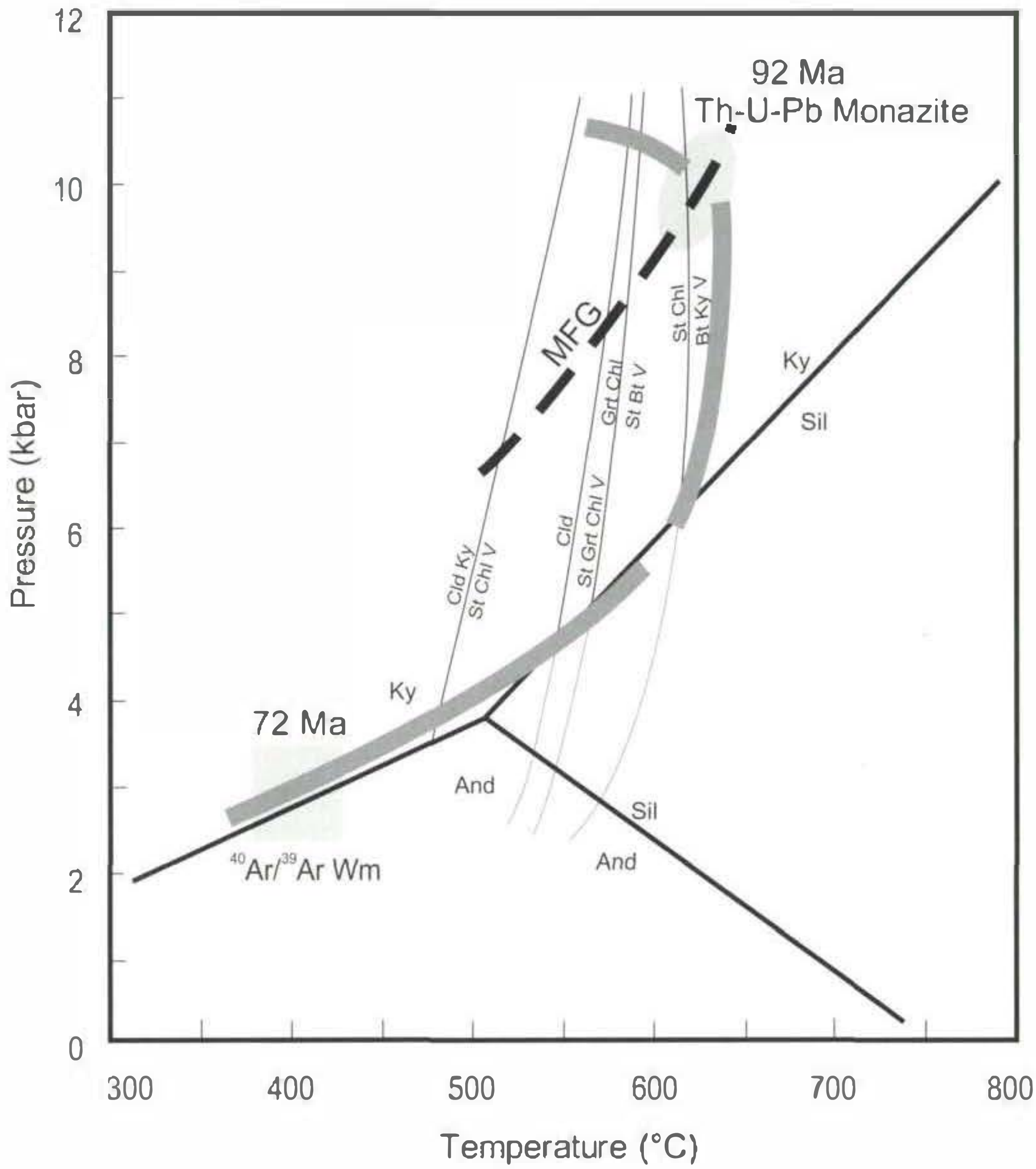

Fig. 2

The southernmost part of the Veporic unit investigated from drillholes in northern Hungary (KOROKNAI et al., 2001) yield lower amphibolite facies metamorphic conditions (c. 550±30°C and 9±1 kbar). K/Ar and $^{40}Ar/^{39}Ar$ dating of micas and amphibole yield exclusively Cretaceous ages (87–95 Ma). Zircon fission tracks of 75–78 Ma and Early Paleogene apatite FT data indicate rapid cooling after the medium-grade Eoalpine event.

These results clearly document the effects of intense- amphibolite facies Alpine metamorphism during Cretaceous time in the central Western Carpathians, analogous to the so called "Eoalpine" events in the Alps. Metamorphism was related to collisional crustal shortening and stacking, following subduction of the Meliata ocean and exhumation occurred by synorogenic (orogen-parallel) extension and unroofing in an overall compressive regime.

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Authors' addresses:
Marian Janak, Dusan Plasienka, Geological Institute, Slovak Academy of Sciences, Dúbravská 9, 842 26 Bratislava, Slovak Republic, geolmjan@savba.sk; Mike Cosca, Institut de Minéralogie, Université de Lausanne, BFSH2, CH-1015 Lausanne, Switzerland; Fritz Finger, Institut fur Mineralogie, Universitat Salzburg, Hellbrunnerstrassse 34, A-5020 Salzburg, Austria; Balazs Koroknai, Geological Institute of Hungary, Stefania. u. 14, H-1143 Budapest, Hungary; Branislav Luptak, Department of Mineralogy and Petrology, Comenius University, Mlynská dolina G, 842 15 Bratislava, Slovak Republic; Peter Horvath, Laboratory for Geochemical Research, Hungarian Academy of Sciences, Budaörsi út, H-1112 Budapest, Hungary