A Metamorphic History from Electron Microprobe Dating of Monazite: Variscan Evolution of The Tatra Mountains

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The recent development of the chemical Th-U-Pb method for *in situ* dating of monazite using an electron microprobe (EMP) has made it possible to determine multiple thermal events during orogenesis (e.g. Montel et al., 1996, Cocherie et al., 1998, Williams et al., 1999). The aim of this study is to constrain a metamorphic history using EMP dating of monazite on example of the Tatra Mts. We compare our results with those obtained from single-grain, cathodoluminescence-controlled, U-Pb dating of zircons (Poller et al., 2000, Poller and Todt, 2000).

Analytical procedure and age determination

Analyses of monazites were carried out using the Cameca SX-100 microprobe. Acceleration voltage of 15 kV was used rather then 25 kV, because of less strong ZAF correction factors. The beam diameter varied from 2 to 6 μm according to the possibilities to analyse only single phase in the monazite. Larger beam diameters were preferred. The REE phosphates were used for the calibration of Er, Yb, Sm, La, Ce, Pr, Y and Nd, pure oxides for the U, Th and PbS for the Pb. Counting times were kept from 80 to 200 s in order to get reasonable peak/background ratio. Pb, U and Th were measured using large PET crystal that is several times more sensitive then the crystal of conventional size. For the calculation of single age we followed the procedures of Montel et al (1996), Suzuki and Adachi (1998) and Nagy (2003). All procedures gave almost the same ages with only negligible deviations. The ages presented here have been calculated by statistical method described in Montel et al (1996).

Samples

The samples selected for this study are metapelites from the Western and High Tatra. Sample ZT 96 is the micaschist from the lower unit in the Western Tatra, where it belongs to the kyanite-fibrolitic sillimanite zone of metamorphism. It contains the assemblage kyanite + fibrolitic sillimanite + garnet + biotite + muscovite + plagioclase + quartz + staurolite. Fibrolitic sillimanite is a relatively younger phase than kyanite. In these rocks, metamorphic *P-T* conditions reached 620–660 °C and 6–8 kbars (Janák, 1994, Ludhová, 1999). Two samples are from the upper unit. Sample ZT 1 is a migmatitic paragneiss from the kyanite zone in the Western Tatra with the assemblage garnet + kyanite + sillimanite + biotite + plagioclase + K-feldspar + muscovite. Kyanite is partly transformed to sillimanite. Sample VT 5 is migmatite of the sillimanite zone from the High Tatra, containing the assemblage garnet + sillimanite + biotite + quartz + plagioclase + K-feldspar + muscovite. Metamorphic *P-T* conditions for these metapelites reached 735–850 °C; 12–13 kbar in the kyanite zone, and 685–825 °C; 5–8 kbar in the sillimanite zone (Janák et al., 1999).

Results

Several grains of monazite were analysed in each sample; some of the larger grains were analysed by multiple spots in order to determine the age distribution. The age histograms demonstrate that two main events have been recorded by the monazite from the migmatitic gneiss (ZT 1) and the micaschist (ZT 96) from the Western Tatra; an older event at 415–395 Ma and a younger one at 380–345 Ma (Fig. 1a, b). In contrast, migmatite (VT 5)

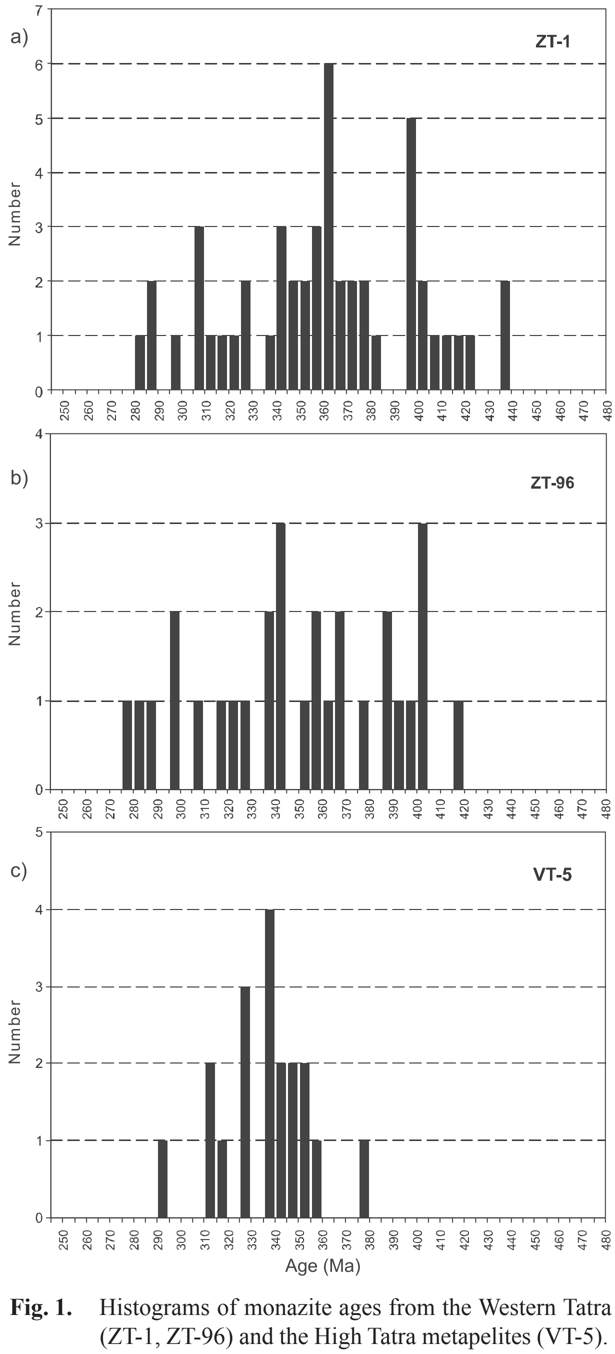

Fig. 1. Histograms of monazite ages from the Western Tatra (ZT-1, ZT-96) and the High Tatra metapelites (VT-5).

from the High Tatra shows only one major metamorphic event at 360–335 Ma (Fig. 1c). Previous EMP dating of monazite from the same sample (VT 5) yields very similar age of 358 Ma (unpublished data of Finger).

The results obtained from EMP dating of monazite are in very good agreement with published zircon ages. Poller et al. (2000) obtained the age of 406 + 5 Ma from single grain cathodoluminescence-controlled dating of zircon from kyanite zone orthogneiss, generated by dehydration melting of metapelites (Janák et al., 2001). In these rocks, some zircons record even younger, c. 360 Ma age of recrystallization. Zircons from the sillimanite zone migmatite (VT 5) show the age of 360–330 Ma (Poller and Todt, 2000). The above results suggest two distinct Variscan metamorphic events in the Tatra Mountains: an older (M1) at c. 410-400 Ma, and younger (M2) at 360–330 Ma. The EMP analysis of monazite shows also very old ages of 900 Ma and 1.43 Ga. These may record the protolith age as inferred from the cores of zircons (Poller et al., 2000). The micaschists contain only clastic zircons of pre-Cambrian age (Gurk, 1999), implying that *P-T* conditions during Variscan metamorphism in these rocks, in contrast to monazite, were too low for growth of zircon. The presence of relatively young (c. 295–325 Ma) domains in monazite may suggest local influence of fluids during late Variscan retrogression and uplift, as recorded by Ar-Ar dating (Janák, 1994).

The data from the monazites show no link between age and composition, which is confirmed by the lack of relationships between age distribution and back-scattered electron images. The age distribution in the individual grain is similar to that in all analysed grains within the sample. This implies rather recrystallization and absence or very minor diffusion of Pb in monazite. The analysed monazite grains appear to preserve a complex metamorphic history during Variscan orogeny.

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Felsic Granulites from the Gföhl Unit (Austria and Czech Republic): Metamorphosed pre-Variscan Metagranites or Visean High-Pressure Melts?

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The genesis of prominent felsic granulites in the southern part of the Bohemian Massif (Gföhl Unit, Moldanubian Zone) with the HP assemblage Grt + Ky + Qtz + ternary feldspar (now mesoperthite) has been a matter of a substantial controversy. While most of the authors agree that the felsic Moldanubian granulites were, at some stage of their evolution, granitic or rhyolitic magmas, it is important to discuss whether:

a) the bulk of felsic granulites formed and segregated as high-pressure melts in a Variscan subduction zone (e.g., Vrána and Jakeš, 1982, Jakeš, 1997, Kotková and Harley, 1999), or