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 Previous EMP dating of monazite from the same sample (VT 5) yields very similar age of 358 Ma (unpublished data of Finger).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

b) the granulites are merely normal felsic igneous rocks of pre-Carboniferous age that were nearly isochemically metamorphosed during the Variscan (Visean) event (e.g., Fiala et al., 1987a, b, Vellmer, 1992), not excluding a possibility that low degrees of partial melting occurred (Roberts and Finger, 1997).

The main points that are difficult to explain by the first scenario are:

1. Whole-rock geochemical signature corresponding to normal felsic igneous rocks

The granulites correspond geochemically to slightly peraluminous, strongly fractionated I-type granitoids. While U, Th and Cs are depleted, most likely due to the HP metamorphism (Vellmer 1992), most of the trace-element contents are comparable to average upper crust and normal felsic igneous rocks. The trace-element trends, such as falling Sr, Ba, Eu, LREE and Zr with rising SiO_2 and Rb, can be explained by fractional crystallization of Kfs, Zrc and Mnz and seem to have been preserved from the igneous stage. Thus, contrary to the opinion of Jakeš (1997), there seems to be no unusual whole-rock geochemical variation that would necessitate the HP melting scenario.

Moreover, if the felsic granulites were essentially restite depleted, HP melts, then restite would inevitably be rich in Grt. If this were the case, then significant HREE and Y depletion should be observed in the melt. Even though there is indeed a sharp decrease in LREE and MREE contents with increasing SiO_2 (compatible with Mnz-dominated fractionation), the HREE and Y remain virtually constant at relatively high levels.

2. Composition close to LP minimum in the Ab–Qz–Or ternary

The position of the frequency maximum in the CIPW normative diagram argues stoutly for low-pressure, essentially eutectic composition of the granulite protolith. The effect of other volatiles, such as F and B, would drive the eutectic composition away from the *Qz* apex (and thus the melting pressure would be over- rather than underestimated: Johannes and Holtz 1996).

3. Small scale Sr/Nd isotopic disequilibria, preservation of Ordovician/Silurian Rb–Sr ages

The felsic granulites contain radiogenic Sr ($^{87}\mathrm{Sr}/^{86}\mathrm{Sr}_{340} = 0.7106 - 0.7706$) and unradiogenic Nd ($\varepsilon^{340}_{\mathrm{Nd}} = -4.2$ to -7.5). Sample pairs collected from adjacent more leucocratic and more biotite-rich facies of Austrian granulites preserve Sr and (in two cases) Nd isotopic disequilibria at the dm/m scale (samples *Popp*: $^{87}\mathrm{Sr}/^{86}\mathrm{Sr}_{340} = 0.730/0.719$, $\varepsilon^{340}_{\mathrm{Nd}} = -7.0/-6.1$; *Ost*: 0.753 / 0.715, −7.5 / −5.7 and *Ysp*: 0.770 / 0.738, −6.2 / −6.4). Assuming an initial equilibrium, the individual pairs would give early Palaeozoic (Ordovician/Silurian) Rb–Sr ages, in line with the results of the previous whole-rock (Arnold and Scharbert, 1973, Janoušek et al., 1996) as well as thin-slab dating (Frank et al., 1990). Given the coincidence of the Rb–Sr systematics with U–Pb ages for many inherited zircon cores (Kröner et al., 2000, Friedl et al., 2003), the Sr isotopes seem to have largely maintained memory of an older igneous protolith. The whole-rock Sr (–Nd) isotopic system apparently failed to re-equilibrate even on a small scale during Variscan metamorphism and any in-situ HP partial melting did not lead to larger scale chemical equilibrium. This was probably due to the low hydrous fluid or melt activity during the HP stage, in conjunction with its presumed short duration (Medaris et al. 1990, 2003).

4. Zircon and monazite saturation temperatures

The Zr concentrations in the felsic granulites are generally low (86 ± 50 ppm; median ± 1σ). These decrease with increasing SiO_2 to less than 50 ppm, which is compatible with Zrc fractionation. The zircon saturation temperatures (Watson and Harrison 1983) are similar to those obtained on the basis of the monazite saturation model (Montel, 1993, both ~ 750 °C).

5. Low Zr concentrations vs. presence of zircon inheritance

If the felsic granulites represent restite-poor, high-PT melts and the source was capable of providing enough Zr, then they should have acquired much higher Zr contents (*ca.* 1100 ppm at 1000 °C: Watson and Harrison, 1983) than observed (mainly < 150 ppm). To invoke dramatic Zr-undersaturation (Kotková and Harley, 1999) seems unrealistic, because almost all the felsic Moldanubian granulites carry abundant pre-Variscan zircon relics (Kröner et al., 2000, Friedl et al., 2003). Moreover, Zr-undersaturated granitic suites show positive SiO_2 – Zr correlations whereas the observed trend is negative.

It follows from the foregoing that a specific, felsic I-type granite suite of Early Palaeozoic age should have been an important constituent of the subducted Gföhl terrane. It should be also noted that the Gföhl gneisses, which were probably part of the same terrane, have a composition resembling that of the granulites (Vellmer, 1992). Furthermore, chemically similar felsic metaigneous rocks can be found in the Saxothuringian Zone, for example amphibolite-facies orthogneisses in the Orlica–Śnieżnik dome in Poland (Franke and Żelaźniewicz, 2000, Turniak et al., 2000, Bröcker et al., 2003) or metagranites and metarhyolites in the Fichtelgebirge (Siebel et al., 1997, Wiegand, 1997).

Particularly in the latter case, the analyses show a good match in most of the elements, save U and Th (Cs), compared to the overall compositional spectrum for the felsic granulites. The latter elements are believed to have been depleted in the granulites during their prograde development. The metaigneous rocks from Fichtelgebirge were dated at 455–480 Ma (Siebel et al., 1997, Wiegand, 1997 and references therein), which falls within the spectrum of inherited ages observed in the granulites. The Sr isotopic system for many of the Fichtelgebirge samples has been disturbed. However, the Wunsiedel orthogneiss gave a whole-rock Rb–Sr age of 480 ± 4 Ma with $^{87}\mathrm{Sr}/^{86}\mathrm{Sr}_{\mathrm{i}} = 0.7095$ (Siebel et al., 1997) and this compares favourably with the mean of the felsic granulites recalculated to 480 Ma (0.7086 ± 0.010, 1σ). Moreover, the $\varepsilon^{480}_{\mathrm{Nd}}$ values for samples from Fichtelgebirge with $SiO_2 > 70\%$ (orthogneisses: −3.5 ± 0.4, metarhyolites: −4.8 ± 1.1) also match the mean $\varepsilon^{480}_{\mathrm{Nd}}$ (−4.9 ± 1.9) for the felsic Moldanubian granulites. Therefore, it seems that Ordovician/Silurian metaigneous crust with a composition resembling that preserved in the Fichtelgebirge could have yielded rocks similar to felsic Moldanubian granulites with relatively negligible geochemical modification upon subduction to depths of at least 50–60 km (O'Brien, 2000).

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