Trabajos de Geología, Universidad de Oviedo, 30 : 316-321 (2010)

Oviedo (Spain) 1-3 July 2008 International Meeting of Young Researchers in Structural Geology and Tectonics

ORSGET

The record of structural evolution and U-Pb zircon dating of the tonalite intrusions (Polička Crystalline Unit, Bohemian Massif)

L. Vondrovic[1, 2*] and K. Verner[1, 2]

[1]*Institute of Petrology and Structural Geology, Charles University, Albertov 6, Prague, Czech Republic.*

[2]*Czech Geological Survey, Klárov 3, Prague, Czech Republic.*

[*]*e-mail: lukas.vondrovic@geology.cz*

Abstract: In this study, we present new structural, AMS, and geochronological data from the Mi etín and Budislav tonalite plutons which intruded the mid-crustal Polička Crystalline Unit (Bohemian Massif, Central European Variscides). Magmatic to solid-state fabrics preserved in the plutons (~350 Ma) presumably reflect strain increments acquired during the last stages of regional tectonometamorphic evolution in the NE part of the Bohemian Massif. We emphasize that careful structural analysis in and around these tonalite plutons combined with geochronology contributed to the solution of geodynamic evolution in the marginal part of the Bohemian Massif during and shortly after ~350 Ma.

Keywords: Variscan orogeny, Bohemian Massif, pluton, fabric, AMS**.**

Many studies have established that structures and fabrics in plutons may record regional paleostrain fields during and after their crystallization (e.g. Paterson *et al.*, 1998; Miller and Paterson, 2001). Careful structural and geochronological analysis of the plutons may thus provide important constraints on the kinematic framework and timing of regional tectonometamorphic processes within orogenic belts. On the basis of this assumption, we carried out a detailed structural analysis of two calc-alkaline plutons (the Mířetín and Budislav pluton) to understand the time and kinematic frame of tectonometamorphic evolution of the NE part of the Bohemian Massif during the Variscan orogeny (Franke, 1989).

Methods

We applied the AMS method (Anisotropy of Magnetic Susceptibility; e.g. Hrouda and Tarling, 1984) to determine and quantify the internal fabrics of the Budislav pluton. The AMS was measured with the KLY-3S Kappabridge apparatus (Jelínek and Pokorný, 1997) and statistical analysis of AMS data was carried out using the ANISOFT package of programs (Hrouda *et al.*, 1990). The AMS data are represented by the k_m, P, and T parameters defined as follows:

$$k_1= (k_1 + k_2 + k_3)/3 \quad (1),$$

$$\mathrm{P}= k_1 / k_3 \quad (2),$$

$$\mathrm{T}= 2\ ln(k_2 / k_3) / ln(k_1 / k_3) - 1 \quad (3),$$

where k_1, k_2, k_3 are the axis of the susceptibility ellipsoid. The k_m parameter represents the mean bulk magnetic susceptibility reflecting the qualitative and quantitative content of magnetic minerals in a rock. The P parameter (Nagata, 1961), called the degree of AMS, reflects the eccentricity of the AMS ellipsoid and thus indicates the intensity of the preferred orientation of magnetic minerals in a rock. The higher

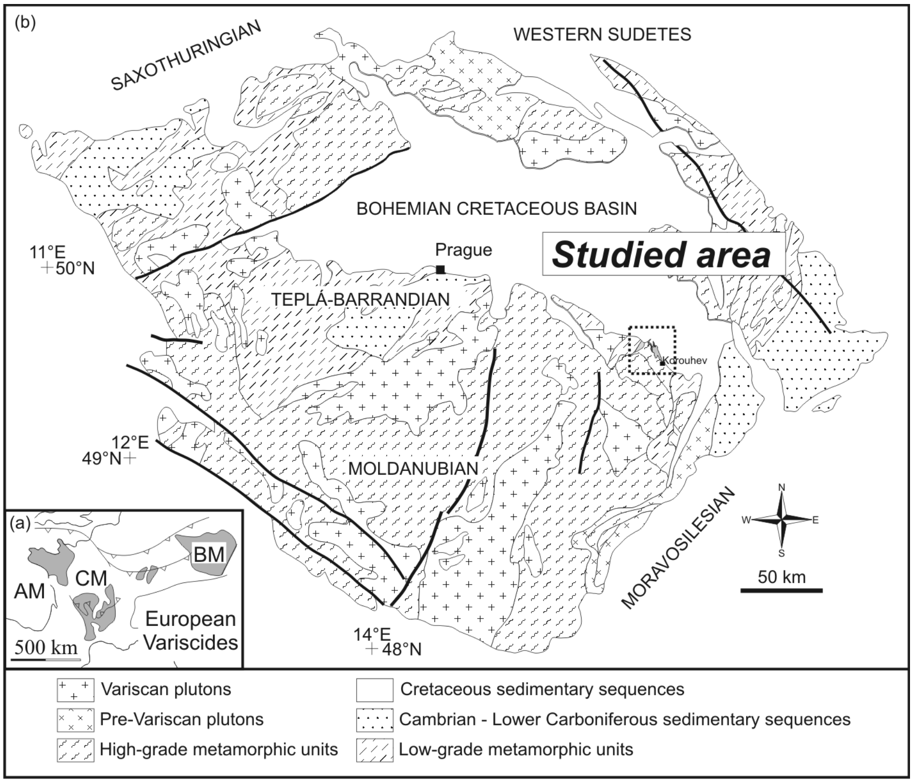

Figure 1. a) Geological sketch of the European Variscides. AM: Armorican Massif, CM: Central Massif, BM: Bohemian Massif, b) geological map of the Bohemian Massif with the studied area highlighted.

value of the *P* parameter indicates the stronger preferred orientation. The *T* parameter (Jelínek, 1981) reflects the symmetry of the AMS ellipsoid. It varies from –1 (linear magnetic fabric), through 0 (transition between linear and planar magnetic fabric) to +1 (planar magnetic fabric).

The radiometric age of plutons was established using the U-Pb method on zircons ($^{207}Pb/^{235}U$, $^{206}Pb/^{238}U$ ratios) measured by LA ICP MS (Laser Ablation Inductively Coupled Mass Spectrometry) at the University of Bergen, Norway.

Structural pattern

Metamorphic host rocks (the Polička Crystalline Unit)

The Poli ka Crystalline Unit (PCU) crops out at the periphery of the exhumed orogenic root (referred to as the Moldanubian Unit) in the NE part of the Bohemian Massif (Fig. 1). The PCU is made up of two-mica gneisses with layers of calc-silicate rocks, marbles, and amphibolites. The regional P-T conditions of the PCU were estimated at ~5 kbar and 590 °C (Buriánek *et al.*, 2006a). The overall structural pattern of the PCU (Fig. 2) is defined by regional metamorphic foliation (pervasive schistosity or compositional banding) which dips steeply to moderately to the NE in the central part of the PCU, and to the WNW in its western part. This foliation bears well-developed, gently plunging NW-SE stretching lineation associated with right-lateral kinematics. During the Variscan orogeny, the PCU was affected by numerous intrusions of calc-alkaline composition (e.g. the Mi etín and Budislav plutons; Buriánek *et al.*, 2003). To the west, the PCU and other mid-crustal units are separated from the overlying upper-crustal metasediments (the Hlinsko Zone) by localized ~NNE-SSW normal faults.

The Miřetín pluton

The Mi etín pluton (MP) has a ~NNE-SSW elongated shape and is composed of deformed medium-grained, porphyritic biotite tonalite to granodiorite. The MP intruded the western margin of the PCU at 348±7 Ma (U-Pb methods on zircons; University of Bergen, Norway). Two distinct solid-state fabrics were recognized in the MP (Fig. 3): I) Pervasive HT solid-state fabric defined by the ductile deformation of biotite and partly recrystallized quartz-feldspathic aggregates (Figs. 4a and 4b). This HT solid-state foliation is associated with subhorizontal stretching lineation and right-lateral kinematics. The orientation and character of this fabric are consistent with metamorphic foliation and lineation in the host metamor-

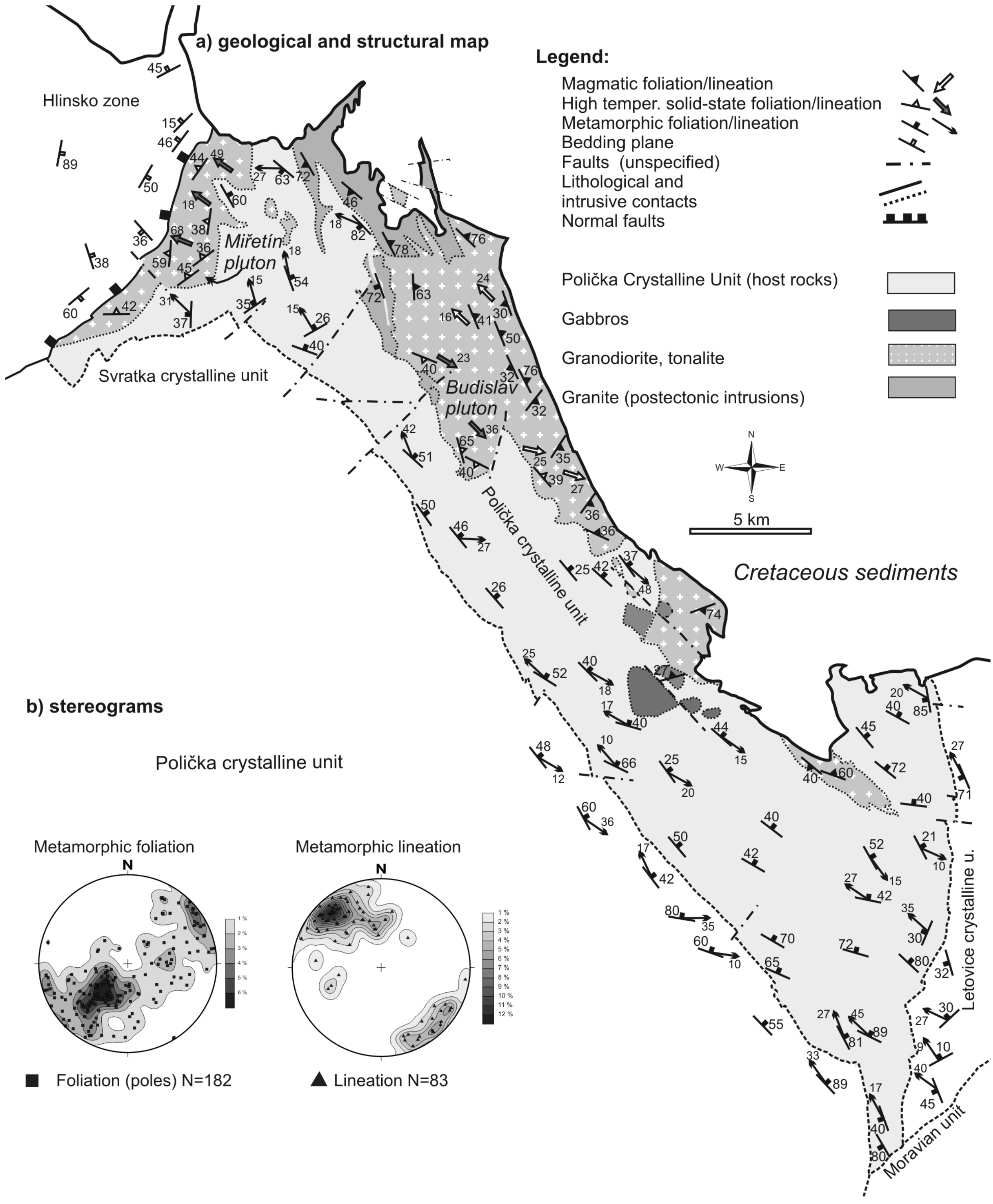

Figure 2. a) Structural and geological sketch of the mid- to upper-crustal Polička Crystalline Unit including the neighbouring metamorphic complexes, b) stereograms (lower hemisphere, equal area projection) of metamorphic foliations and lineations.

phic rocks. II) Discrete LT solid-state fabric developed as spaced cleavage (Figs. 4a and 4b). This LT deformation event affected only the western margin of the MP. The LT cleavage dips at moderate angles to the WNW and is asociated with strongly developed stretching lineation and west-side-down kinematics.

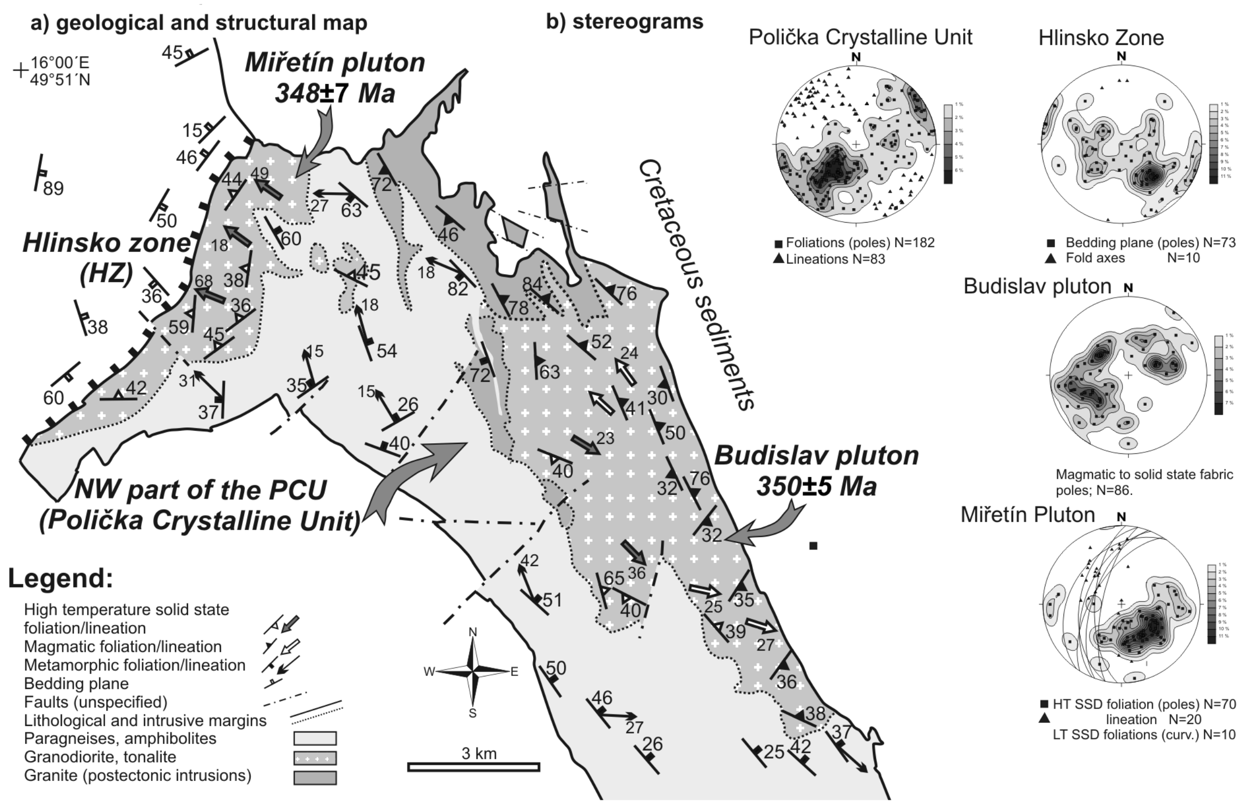

Figure 3. a) Structural and geological scheme of Polička crystalline Unit, Miřetín and Budislav plutons, b) stereograms (lower hemisphere, equal area projection) of structural measurements.

This LT fabric is probably connected with normal faulting along the PCU-Hlinsko Zone tectonic boundary.

The Budislav Pluton

The Budislav pluton (BP) is composed of fine grained amphibole-biotite tonalite to granodiorite (Figs. 4c and 4d.). The BP intruded the central part of the PCU at 350±5 Ma (U-Pb method on zircons; University of Bergen, Norway). Multiple magmatic to solid-state fabrics are recognized in the BP (Fig. 3): I) M_1 magmatic foliations, defined by shape-preferred orientation of plagioclase and biotite aggregates, dip steeply to the SE, and II) M_2 magmatic to solid-state foliation, characterized by continuous transition from magmatic to HT solid-state deformation (Figs. 4c and 4d), dips moderately to the ~NE-SW. The M_2 foliation is associated with subhorizontal mineral (magmatic) and stretching (solid-state) lineations (L_2). This fabric is parallel both to the pluton margin and to the regional metamorphic fabric in host rocks.

The AMS fabric was investigated in 20 localities in the BP. The mean bulk magnetic susceptibility (k_m) is relatively homogeneous and low, ranging from 171 to 672×10^{-6} (SI). The values of k_m in the order of 10^{-4} indicate that the paramagnetic mineral phases (biotite and amphibole) are the carriers of the AMS. The degree of AMS (P parameter) ranges from 1.033 to 1.218; the P parameter shows no significant gradient in the pluton. In several cases, the higher values of parameter P correlate with the presence of HT solid-state deformation. Susceptibility ellipsoids exhibit prolate to oblate character, T parameter ranges from –0.987 to 0.9. The orientation of magnetic foliations and lineations is consistent with the measured mesoscopic fabrics (Fig. 2b).

Conclusions

The temporal and geometrical relationships of structures and fabrics in and around the studied calc-alkaline plutons provide important constraints for the kinematic framework and timing of geodynamic processes along the periphery of the exhumed orogenic root in the Bohemian Massif during and shortly after ~350 Ma.

The formation of HT solid-state fabric in the Mi etín pluton (dated at 348±7 Ma) is clearly connected with

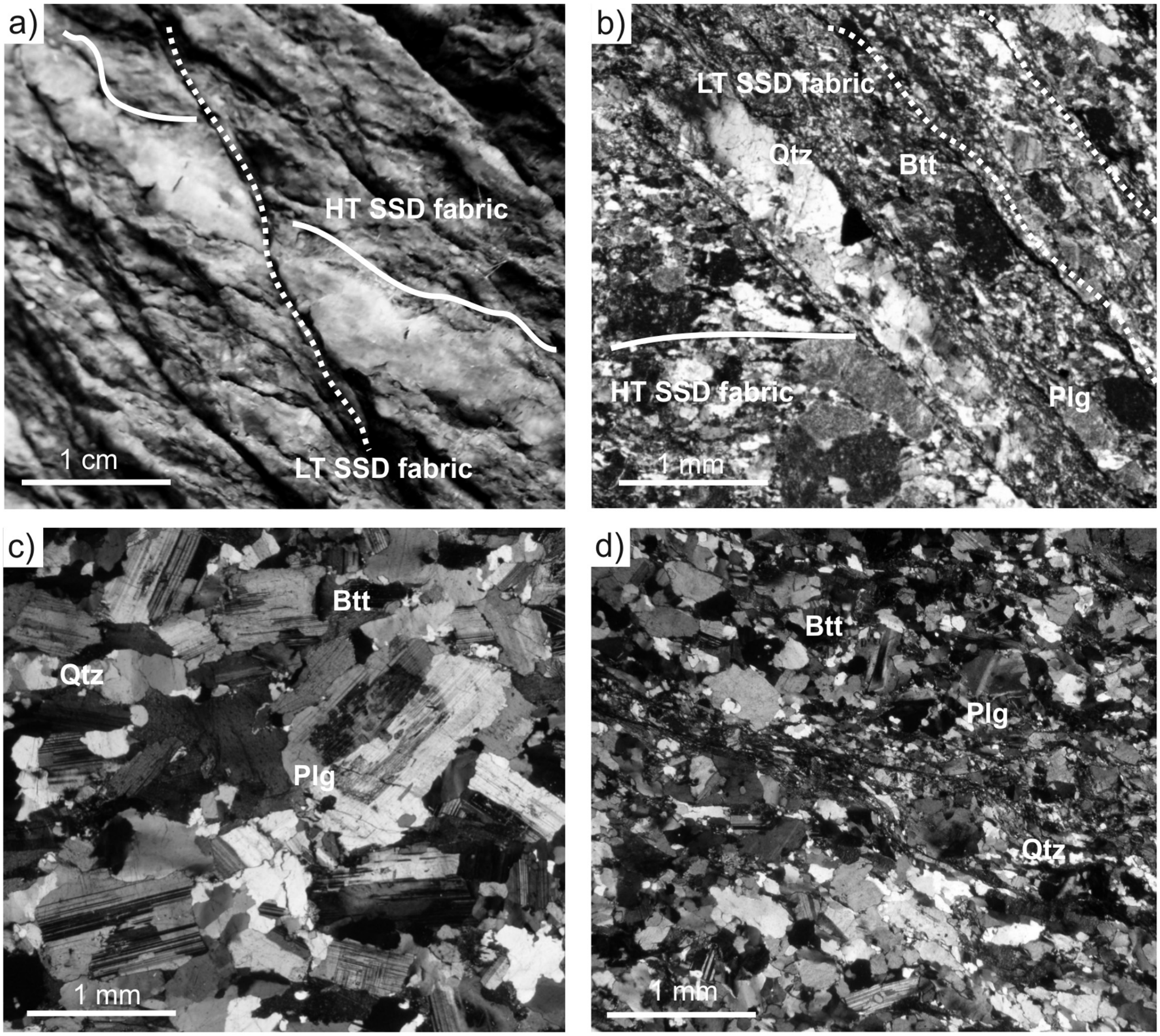

Figure 4. Macro and microphotographs from Mi etín and Budislav plutons: a) Miřetín pluton: the LT-cleavage superimposed on the older high-temperature solid state fabric, b) Miřetín pluton: microstructural record of figure 4a, c) Budislav pluton: magmatic fabric marked by alignment of plagioclase and biotite grains coupled with low internal crystal deformation, d) Budislav pluton: solid state fabric marked by recrystallized biotite, polygonal grains of recrystallized quartz and feldspar. HT SSD: high temperature solid state. LT SSD: low temperature solid state.

the regional orogenic deformation in the western part of the PCU. The overprinting LT cleavage reflects later west-side up normal faulting along the boundary between mid- and upper-crustal units (PCU and Hlinsko Zone, respectively).

The Budislav pluton (dated at 350±5 Ma) intruded the central part of the PCU. Here, the discordant ~NE-SW magmatic foliations are likely to have recorded intrusive strain during the emplacement of the pluton. These fabrics were overprinted by NW-SE regional magmatic to HT solid-state foliation associated with subhorizontal mineral and stretching lineation. The latter magmatic fabric is interpreted as recording increments of the regional orogenic deformation.

The pervasive metamorphic fabric in the PCU is interpreted as being a result of regional dextral shearing under amphibolite facies conditions (P ~5 kbar and T ~590 °C) throughout the NE part of Variscan orogenic root at around 350 Ma.

Acknowledgements

This research was funded by Czech Geological Survey Research Project No. 6352 (to Jaroslava Pertoldová) and by a project of the Grant Agengy of Charles University No. 81909: *The mechanism of emplacement of the particular plutons of the northern part of the Moldanubia; implications for tectonic evolution of the eastern margin of the Bohemian Massif.* We would like to thank Jan Košler (University of Bergen) for precise zircon geochronology and Josep Poblet for his review. We also thank David Buriánek for his cooperation in the field and helpful discussions.

References

BURIÁNEK, D., NĚMEČKOVÁ, M. and HANŽL., P. (2003): Petrology and geochemistry of plutonic rocks from the Poli ka and Záb eh crystalline units (NE Bohemian Massif). *B. Czech Geol. Surv.*, 78: 9-22.

BURIÁNEK, D., BŘÍZOVÁ, E., ČECH, S., ČURDA, J., FÜRYCH, V., HANŽL, P., KIRCHNER, K., LYSENKO, V., ROŠTÍNSKÝ, P., RÝDA, K., SKÁCELOVÁ, D., SKÁCELOVÁ, Z., VERNER, K. and VÍT, J. (2006a): *Vysv tlivky k základní geologické map R 1:25,000* 24-112 Jedlová. MŽP, Archiv ČGS.

FRANKE, W. (1989): Variscan plate tectonics in Central Europe – current ideas and open questions. *Tectonophysics*, 169: 221-228.

HROUDA, F. and TARLING, D.H. (1984): *The magnetic anisotropy of rocks*. Chapmann and Hall, London, 215 pp.

HROUDA, F., JELÍNEK, V. and HRUŠKOVÁ, L. (1990): A package of programs for statistical evaluation of magnetic data using IBM-PC computers. *Eos Trans., Am. Geophys. Union*. San Franscisco: 1289.

JELÍNEK, V. (1981): Characterization of the magnetic fabric of rocks. *Tectonophysics*, 79: 63-67.

JELÍNEK, V. and POKORNÝ, J. (1997): Some new concepts in technology of transformer bridges for measuring susceptibility anisotropy of rocks. *Phys. Chem. Earth*, 22: 179-181.

MILLER, R. B. and PATERSON, S. R. (2001): Influence of lithological heterogeneity, mechanical anisotropy, and magmatism on the rheology of an arc, North Cascades, Washington. *Tectonophysics*, 342, 3, 4: 351-370.

NAGATA, T. (1961): *Rock Magnetism*. Maruzen Ltd. Tokyo, 350 pp.

PATERSON, S. R., FOWLER, T. K., SCHMIDT, K. L., YOSHINOBU, A. S., YUAN, E. S. and MILLER, R. B. (1998): Interpreting magmatic fabric patterns in plutons. *Lithos*, 44: 53-82.