Emplacement, structural and P-T evolution of the 346 Ma Miřetín Pluton (eastern Teplá-Barrandian Zone, Bohemian Massif): implications for regional transpressional tectonics - Discussion

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Discussion

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Introduction

Vondrovic et al. (2011) describe magmatic to solid-state fabrics in the so-called Miřetín Pluton, which intruded in the central–eastern part of the Bohemian Massif, along the tectonic contact between the Hlinsko Unit in the hanging wall and the Svratka and Polička units in the footwall. The authors infer that the Pluton intruded in a transpressional domain along the eastern margin of the Teplá–Barrandian Zone and experienced an early submagmatic to high-temperature (HT) solid-state deformation in a transpressional regime before a subsequent, low-temperature (LT) deformation associated with normal kinematics. They acknowledge that this interpretation is "at variance with the earlier concepts of Pitra et al. (1994)", who studied the pluton and the adjacent rocks of the Hlinsko and Svratka units in some detail and concluded that the pluton was emplaced syntectonically into a ductile normal shear zone. Interestingly, most features described in the granodiorite are identical to those reported in Pitra et al. (1994), and the interpretation only is different. The goal of this contribution is to emphasize that the analysis of Vondrovic et al. (2011) does not take into account some important, regional features and that the interpretation proposed by Pitra et al. (1994) remains valid.

1. Teplá–Barrandian?

As a foreword, from a regional point of view, it is regrettable that the authors assume that the Hlinsko Unit belongs to the Teplá–Barrandian Zone, whereas there is evidence that this interpretation is no fact. Indeed, many authors suggested that the sedimentary character of the Hlinsko Unit (in particular the Silurian Mrákotín Series) is quite different from the Barrandian equivalents (Wurm 1927; Kettner 1931; Kodym 1946; Štorch and Kraft 2009). As suggested by Pitra et al. (1994), rather than the Miřetín Pluton, it may be the Nasavrky magmatic complex that intruded along the contact between the Teplá–Barrandian and the various peri-Moldanubian units (whether or not they belong to the Moldanubian) in this region. Accepting this uncertainty and possibility could have avoided Vondrovic et al. (2011) vainly striving to find arguments for the transpressive character of the eastern margin of the Teplá–Barrandian Zone in the Miřetín Pluton.

2. The Miřetín Pluton

With respect to the deformation pattern of the Miřetín intrusion, both Pitra et al. and Vondrovic et al. report a sequence of submagmatic, HT solid-state and LT solid-state structures. Both describe the relics of submagmatic flow preserved by the shape preferred orientation of magmatic feldspar crystals. Both report the presence of myrmekite and "mica-fish" texture of biotite crystals. Both describe the presence of quartz ribbons with quartz grain boundaries testifying to HT grain boundary migration and the preferred orientation of quartz lattice pointing to the dominant activity of prism <a> slip, characteristic of deformation at relatively high temperature. Finally, both report crystal size reduction and partial transformation of biotite to chlorite, suggesting decreasing temperature during formation of the late shear bands. Whereas both papers agree that the late shear bands were related to normal shearing, the interpretation of the kinematics of the HT fabric is different.

Pitra et al. (1994) use the following observations to argue that the HT fabric was also related to the same north-westward normal shearing: 1) Quartz + K-feldspar-filled microfractures in plagioclase phenocrysts are interpreted as resulting from deformation at the submagmatic stage (op. cit. p. 20). Their obliquity with respect to the foliation defined by the shape preferred orientation of the plagioclase crystals is consistent with top-to-the-NW shear (op. cit. Fig. 6). 2) The shape of the biotite "fishes" (op. cit. Photo 4, Fig. 6) shows normal movement to the NW. 3) Polycrystalline quartz ribbons are parallel to the foliation. Recrystallised grains are slightly elongated and define an internal shape fabric oblique to the foliation. This obliquity indicates a normal, NW-directed kinematics. 4) Quartz c-axes fabrics define incomplete girdles (op. cit. Fig. 7). The girdle obliquity to the foliation is consistent with a north-westward shear deformation. Hence, all the HT and the LT features point to consistent kinematic conditions and thus may be attributed to a single progressive deformation affecting the pluton during cooling in a normal top-to-the-NW shear. These textural and structural features are typical of syntectonic intrusions (e.g. Gapais 1989; Paterson et al. 1989), in particular within normal shear zones, which are suitable for a rapid transition from HT to LT deformation.

Vondrovic et al. (2011) disregard these arguments and refer instead to the "asymmetry of mineral aggregates and folded leucogranite dikes" (op. cit. p. 349, Fig. 4b–c) to argue that the HT deformation was associated with thrusting. However, the illustrations fail to convince. The validity of the first argument is impossible to appreciate: in Fig. 4b, two supposed aggregates are suggestively overdrawn with thick white lines. The shape of the smaller one cannot be used as a shear-sense indicator (despite the arrows) and other aggregates are either not clearly visible, or indicate an apparently normal kinematics. Figure 4b was shown to several knowledgeable scientists, and they all wondered whether the authors were familiar with S/C structures. Furthermore, it is worth pointing out that the apparent asymmetry of mineral aggregates may be an ambiguous tool unless the features are well described and the underlying processes correctly interpreted (e.g. Van Den Driessche and Brun 1987; Hanmer and Passchier 1991). Similarly, the significance of fold asymmetry is known to be no reliable kinematic indicator as folding is a complex process that installs local conditions that do not reflect regional strain fields. For example, any textbook, for more than a century, documents the inversion of second order fold asymmetry from one limb of a first order fold to the next limb, whatever the regional transport direction. Unless a regionally extensive study is performed and the orientation of fold axes measured systematically, and fold axes demonstrated not to have been rotated towards the shear direction (e.g. Skjernaa 1980; Hanmer and Passchier 1991), folds cannot be used to interpret large-scale deformation regimes. A much better argumentation should be expected if any previous interpretation is to be defied.

3. The Hlinsko Unit

In the overlying Hlinsko Unit, the intrusion of the pluton produced low-pressure high-temperature metamorphism, which is well developed in the Mrákotín Series (Pitra et al. 1994; Pitra and Guiraud 1996). The metamorphic minerals, in particular staurolite and chloritoid, display shape preferred orientation and define a mineral lineation oriented NW–SE (Pitra et al. 1994, Fig. 5), consistent with the orientation of the stretching lineation in the underlying pluton. The crystallisation of these minerals was syntectonic and asymmetric crystallisation tails and sigmoidal inclusions indicate a NW-ward shearing (op. cit. Photos 2–3), contemporaneous with the emplacement of the pluton.

4. The Svratka Unit

Finally, Vondrovic et al. (2011) claim that the "low-T solid-state fabrics", associated with "W-side-down kinematics", "occur only in a narrow zone (up to 0.5 km wide) along the western flank of the Pluton" (p. 349). This is partly correct but evident, since cooling causes localized deformation, hence narrowing of the deformation zones. The LT fabrics are indeed concentrated along the contact of the pluton with the Hlinsko Unit, leading locally to the development of ultramylonites. This is normal; the contact zone with cold country rocks is where magma cools faster. However, NW-ward shearing is documented in a wide band including not only the entire pluton, but also the rocks of the underlying Svratka crystalline unit (Pitra et al. 1994, p. 19, Photo 5) up to several km below the contact of the pluton with the Hlinsko Unit (e.g. outcrops at the southern end of Krouna, or in the surroundings of Herálec and Svratka).

5. Conclusions

In conclusion, the evidence that the Miřetín Pluton intruded syntectonically along the contact between the overlying Hlinsko Unit and the underlying Svratka (and Polička) Unit during a north-westward normal shearing remains strong, even if Vondrovic et al. (2011) would like to prove the contrary. This shearing accompanied the cooling of the pluton and is documented at all stages of the deformation, from the submagmatic, through the HT solid-state to the LT solid-state deformation stage. This shearing is also documented in the syntectonic contact-type metamorphic assemblages in the Hlinsko Unit, as well as in the micaschists and orthogneisses of the underlying Svratka Unit (cf. Paterson et al. 1989, p. 359). Hence, the transpressive character of the contact between the Hlinsko Unit and the Svratka and Polička units stands as a blunder due to the limited amount of information Vondrovic et al. (2011) have gathered from the pluton only. The conclusions of Pitra et al. (1994) are based on a significantly more detailed and more complete piece of work. The contact between the Hlinsko Unit on the one hand, and the Svratka and Polička units on the other, is a normal shear zone along which the pluton intruded syntectonically.

References

GAPAIS D (1989) Shear structures within deformed granites: mechanical and thermal indicators. Geology 17: 1144–1147

HANMER S, PASSCHIER C (1991) Shear-sense indicators: a review. Geological Survey of Canada Papers 90–17: 1–72

KETTNER R (1931) O postavení metamorfovaných ostrovů v oblasti středočeského žulového masivu. Sborník SGÚ 9: 301–308

KODYM O (1946) Moldanubická zona variská v Čechách (La zone varisque moldanubienne de la Bohême). Sborník SGÚ 13: 69–125

PATERSON SR, VERNON RH, TOBISCH OT (1989) A review of criteria for the identification of magmatic and tectonic foliations in granitoids. J Struct Geol 11: 349–363

PITRA P, GUIRAUD M (1996) Probable anticlockwise P–T evolution in extending crust: Hlinsko region, Bohemian Massif. J Metamorph Geol 14: 49–60

PITRA P, BURG JP, SCHULMANN K, LEDRU P (1994) Late orogenic extension in the Bohemian Massif: petrostructural evidence in the Hlinsko region. Geodin Acta 7: 15–30

SKJERNAA L (1980) Rotation and deformation of randomly oriented planar and linear structures in progressive simple shear. J Struct Geol 2: 101–109

ŠTORCH P, KRAFT P (2009) Graptolite assemblages and stratigraphy of the lower Silurian Mrákotín Formation, Hlinsko Zone, NE interior of the Bohemian Massif (Czech Republic). Bull Geosci 84: 51–74

VAN DEN DRIESSCHE J, BRUN JP (1987) Rolling structures at large shear strain. J Struct Geol 9: 691–704

VONDROVIC L, VERNER K, BURIÁNEK D, HALODOVÁ P, KACHLÍK V, MÍKOVÁ J (2011) Emplacement, structural and P–T evolution of the ~346 Ma Miřetín Pluton (eastern Teplá–Barrandian Zone, Bohemian Massif): implications for regional transpressional tectonics. J Geosci 56: 343–357

WURM A (1927) Stáří buližníků v okolí Hlinska (L'âge des lydites des environs de Hlinsko). Věstník SGÚ 3: 247–255