Sources, Emplacement Environments, and Metamorphic Evolution of Metagabbros in the Mariánské Lázně Complex and Teplá Crystalline Unit (NW Bohemian Massif)

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Bodies of metamorphosed rocks of gabbro-diorite series occur in the Mariánské Lázně Complex (MLC) and in the Teplá Crystalline Unit (TCU) along the western margin of the Teplá–-Barrandian Unit. Two main groups of gabbroic rocks can be distinguished in relics and small bodies scattered over the area: (1) MORB-like gabbro series formed the protolith of some eclogites preserved in relics in the central part of the Mariánské Lázně Complex. The eclogitized rocks underwent a post--eclogite metamorphism together with rocks from the mixed source (Beard et al. 1995) and probably also with segments of continental lower crust. (2) Garnetiferous coronitic metagabbros of the second series predominate in the NW part of the Teplá Crystalline Unit and its external contact with the Mariánské Lázně Complex. The present study is concentrated on the latter group of coronitic metagabbros that record the maximum metamorphic overprint corresponding to upper amphibolite facies.

The detailed sampling and new geochemical data for gabbros from MLC and TCU brings a new insight into mutual relationships of the MLC/TBU metagabbros. Coronitic metagabbros, locally strongly deformed and amphibolized, form the entire south-eastern margin of MLC, and are scattered also within the metasediments and orthogneisses of the TCU. The group of gabbroic rocks comprises equigranular metagabbros with variable rock-forming minerals and rare metadolerites and metagabbro porphyries (Stedra 1996). Dynamically recrystallized, deformed metagabbros transformed into garnetiferous amphibolites predominating along the MLC/TCU boundary. In the TCU, a less pronounced prograde and retrograde metamorphic overprint of primary magmatic mineral assemblage is documented from some metagabbro bodies. A low fluid activity in combination with heterogeneous deformation in the low-strain domains of these basic bodies limited probably the kinetics of metamorphic reactions in metabasic rocks.

New geochemical data on MLC and TCU medium-grade metagabbros indicate the presence of several types of gabbroic rocks. These groups vary in mineral and geochemical composition; the types recognized are Mg-rich olivine-bearing two-pyroxene, Ti-rich cpx-pl, Ti-rich plagioclase-rich, low-Mg transitional two-pyroxene, and low-Mg biotite- and amphibole-bearing metagabbro, respectively. Rocks belonging to these groups are not at all affected by the presence of tectonic boundary between the Mariánské Lázně Complex and the Teplá Crystalline Unit, as it was suspected by Svobodova (1993). Isotope Sm-Nd data for two samples of metagabbro (Eps_{Nd} 6.4 and 6.6; $^{87}Sr/^{86}Sr$ above 0.7037, $^{143}Nd/^{144}Nd$ 0.512902 – 0.512939, Beard et al. 1995) indicate that at least the two gabbros could not have originated as a result of mid-oceanic rifting. Trace- and REE-contents in addition to the isotopic ratios in metagabbros from the TCU-MLC boundary, show better than MORB the within-plate sub-continental source.

Close relation between contact metamorphic assemblages of the Late Cadomian (Cambrian) Lestkov granite and adjacent gabbros shows that these rocks originated in relatively short time interval (518 – 596 Ma, Aftalion et al. 1991, Dörr et al. 1992). Replacement of contact metamorphic cordierite by typical Barrovian assemblage minerals such as kyanite, staurolite, and anthophyllite-gedrite (Kachlík 1997) shows clearly that the MP regional metamorphism was younger than Cadomian orogeny. It was younger than the Cambrian intrusions, i.e., most likely Variscan as indicated by Ar-Ar dating of micas (Dalmeyer and Urban 1994, Kreuzer et al. 1990) and HP metamorphism of eclogite (Beard et al. 1995).

The contact aureole around the Cadomian Lestkov pluton and associated gabbros shows that these rocks, located along the boundary of staurolite and garnet isograd of the Teplá metapelites, caused the growth of HT contact minerals in the adjacent gabbro body (Kachlík in prep). Ambiguous field relationships of gabbroic bodies and host rocks in the TCU, as well as a short interval of emplacement of both Cadomian granitoids and metagabbros (minimum 496 ± 1 Ma of the Výškovice gabbro, and maximum 518 Ma of the Hanov orthogneiss protolith age), indicate a short interval of emplacement of both granitoids and gabbros into the metasediments of the TCU.

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Mechanical Collapse of Vertically Extruded Orogenic Root System: SW Moldanubian Zone

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We investigated the structure and PT evolution of two contrasting crustal levels within the internal part of the Moldanubian orogenic root which are separated by the N-dipping normal fault. The E-W cross-section S of the Kravsko fault comprises from the W to the E: middle – crustal rocks of the Monotonous group, the lower -crustal Gföhl and Raabs units, the Drosendorf window (composed of the middle-crustal Varied unit, paragneisses and amphibolite complex in the E) and the lower -crustal granulitic complex adjacent to the Moravian zone. The cross-section N of the Kravsko fault is traced from the Monotonous unit through the Raabs unit containing eclogites and granulites to the Gföhl unit.

The oldest high-grade fabric in the studied area is best preserved in the southern cross-section. This fabric is represented by a N-S trending subvertical syn – metamorphic foliation S_1, fairly well preserved in schists of the Monotonous group, dominant in the Gföhl gneiss and granulites and well-developed in the Varied group. In the eastern lower crustal segment, the S_1 fabric becomes shallower and dips under medium angles to the W-NW. The S_1 foliation is progressively folded by open to isoclinal folds F_2 with subhorizontal axial planes parallel to the metamorphic foliation S_2. In the Monotonous group, the S_2 foliation is heterogeneous and dips to the SE, in the Gföhl gneiss is missing, in the Raabs unit is subhorizontal and pervasive. The S_2 foliation is flat in the Varied group whereas in migmatites of the eastern lower – crustal segment dips to the NW and exhibits kinematic criteria indicating normal shearing. In all units except the Varied group the, D_2 fabrics are characterized by conditions of partial melting. The S_2 flat-lying foliation is in the Varied group folded by steep folds which is later refolded by subhorizontal folds. Towards the N, this structural pattern is complicated by S-dipping shear-zone with an intense N-S stretching lineation which is developed in both the Monotonous and Varied groups. This structure is contemporaneous with the S_2 foliation in other areas. Further to the E, the shear zone geometrically coincides with the Kravsko fault. N of this prominent fault, the flat S_2 fabric in granulites and amphibolites of the Raabs unit is dominant, locally preserving relics of S_1 foliation. The S_2 fabric is affected by numerous extensional structures such as shear bands, asymmetrical pull-apart boudinage and extensional gashes filled by melts. The Gföhl unit shows similar structural pattern which is locally overprinted by brittle-ductile extensional N-dipping shear zones in the vicinity of the Kravsko fault.

It is important to understand at what depth and thermal conditions the transition from vertical to horizontal fabrics takes place. Therefore, we studied lenses of crustal eclogites and granulites in the Raabs unit and adjacent middle crustal units (Monotonous group and Drosendorf window). The omphacite relics in the eclogites and the relict ky-grt-rt assemblage in granulites testify the HP stage. During the M_2 metamorphism (consistent with flat S_2 fabric) an amp-grt-pl-qtz assemblage in the eclogites has developed, which is equivalent to association found in amphibolites. For the granulites and paragneisses characteristic the M_2 assemblage sil-grt-bt-qtz-pl is characteristic. The conditions of M_2 metamorphism were in all the lithologies calculated at 700–850 °C / 9-13 kbar. In the Monotonous, group the sil-grt-pl-qtz-bt-kfs in paragneisses and the cpx-amp-pl assemblages in amphibolites give evidence of the HT stage. Near the contact with the Moldanubian pluton, the sillimanite becomes unstable and cordierite originates through a reaction sil + bt = crd + ms which is a result of decompression under 6 kbar at T > 650 °C. In the Drosendorf window, the sil-grt-pl-qtz-bt assemblage is stable in paragneisses and amp-grt-pl in the amphibolites yielding the PT conditions of ~700–800 °C / 8–10 kbar.

The distribution of the lower and middle crustal complexes and steep S_1 fabrics S of the Kravsko fault are interpreted in terms of successive extrusion of the lower crust over the basement to the E and over the middle crust in the central part of the root. The E-W shortening of the root produced vertical N-S trending fabrics in all structural levels (lower granulitic crust and middle crust) producing a positive flower structure within the Gföhl unit which extruded symmetrically over the western Montonous unit and the easterly-lying Varied unit. The second extrusion occurred at along the boundary of the Moravian complex where the root was thrust over the Moravian basement. This extrusion brings to middle crustal levels rocks from the base of the orogenic root (16–18 kbar / 800 °C, O Brien 2000) through relatively narrow vertical channels. The S_2 fabrics represent a mechanical collapse of vertical fabrics of the extruded lower and middle crustal material. The highest extruded and rheologically weakest lower crustal rocks of the Raabs and Gföhl complexes show almost entire flat reworking. The PT conditions of the horizontal flow in the extruded lower-crustal rocks correspond to 9–10 kbar / ~800 °C. The underlying middle crustal rocks show similar pressure range and temperatures between 700–800 °C. However, these rocks show evidence of only partial vertical shortening and reworking. We suggest that the collapse of vertical “syn-extrusion” fabrics should not be exclusively gravitational but may be associated with a subhorizontal shearing due to lateral flow of the weak crustal material.