Whole-rock geochemical and mineralogical constraints on the genesis of the metagneous Variscan lower crust in Central Europe – case study of the Lišov granite Massif, Southern Bohemia

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The Gfohl Unit of the Moldanubian Zone, Bohemian Massif, has become a classic and much investigated terrain, as many of the Variscan granite occurrences, associated with mantle-derived peridotite and pyroxenite, are concentrated here. The Lišov granite Massif (LMG) E of České Budějovice (S Bohemia) shows major differences from the neighbouring granite bodies (e.g., the Blanský les Massif) (Vajner 1964; Vrána – Jakše 1982; Vrána 1990; Kotková 1998; Janousek – Vrána 1999):

(i) Much greater relative proportion of intermediate and mafic granulites;
(ii) Abundance of Opx-bearing types (gabbroic and quartz dioritic granulites to relatively felsic hornfelses);
(iii) Limited evidence for the high-pressure metamorphism but prolonged MP–HT (pyroxene granulite-facies) equilibration;
(iv) Absence of aluminosilicates in the felsic Grt-bearing granulites;
(v) Association with spinel peridotites and pyroxenites devoid of garnet;
(vi) Complete absence of eclogites.

The timing of the MP–HT metamorphism is given by the U–Pb zircon age for the mafic two-pyroxene granulite (340 ± 3 Ma: van Breemen et al. 1982) that is in line with the established age of the granulite-facies crystallization in the region (Kröner et al. 2000).

The Lišov granulites define a calc–alkaline trend spanning a range of compositions from basic (gabbroic/quartz dioritic) to leucogranitic (total SiO₂ range 46.7–79.6 wt. %). The Harker diagrams display strong negative correlations of SiO₂ with TiO₂, Al₂O₃, FeOt, MgO and CaO, while K₂O and A/CNK form rather poorly defined positive trends. Finally, the plots with Na₂O, P₂O₅ and mg are characterized by inflections or discontinuities at SiO₂ ~ 55–60 % and, or, SiO₂ ~ 70 % indicative of either a complex evolution or, more likely, presence of several petrogenetic suites, each with a relatively independent history.

Concerning the trace elements, silica is strongly negatively correlated with Cr and Sr (for SiO₂ >50 %, i.e. except for mafic Grt granulites of Kotková 1998). Thorium generally decreases, and Y (for SiO₂ >50 %) increases with SiO₂. The SiO₂–Rb plot displays a poorly defined positive trend but the concentrations of Rb are low in all rock types. The diagrams of SiO₂ vs. Ba, La and Zr show scattered convex upward patterns, with an inflection at SiO₂ ~ 60–65 %. On the basis of petrology, mineral compositions and whole-rock geochemistry, four main rock groups were distinguished:

(1) Mafic two-pyroxene granulites of quartz dioritic–gabbroic composition (LM qtzD), constitute two larger (c. 4 km²) bodies near Zvíkov, in the E of the Lišov mass. These are finer-grained, foliated rocks with mineral assemblage Opş–Cpx–Bt–Pl–Qtz (~ Kfs, Amph, Grt); Ilm, Ap and Zrn are common accessories. Pyroxenes together with Bt and Pl occur in an equilibrated granular mosaic texture. High-Ca pyroxene is light grey-green, nearly non-pelchoeric, with some fine Opx lamellae. Hypersthene shows a strong pleochroism, X: light red-brown, Y: beige, Z: light grey-green.

The metaluminous (A/CNK = 0.73–0.89) granulites LM qtzD are characterized by K₂O/Na₂O < 1 (0.2–0.8), within the data set the highest Sr (median = 533 ppm) and Cr (71 ppm) accompanied by the lowest Rb (27 ppm) and Y (25 ppm). They have moderately LREE-enriched REE patterns (Ce/Yb ~ 5.8–6.4) with slight negative Eu anomalies (Eu/Eu* = 0.80–0.86). The analysed two samples are isotopically the most primitive (87Sr/86Sr ~ 0.7063 and 0.7067, εNd ~ -1.6 and -2.4).

The modally layered sequences (e.g., Rudolfova) document the role for fractional crystallization in the genesis of the presumed gabbroic–quartz dioritic magmatic protolith to the granulites LM qtzD. The trends in the Harker plots are consistent with a fractionation of mainly Amph–Pl assemblage, + pyroxene.

The rare Grt-bearing modally layered granulites described from the borehole LV-1 (Kotková 1998) have significantly flatter, in respect to the rest of the group LREE-depleted patterns (Ce/Yb ~ 2.0–2.9) with variable Eu anomalies. Some geochemical trends (increase in SiO₂, MgO and mg# accompanied by drop in Sr, Y, TiO₂, Al₂O₃, FeOt, SREE, diminishing Eu anomaly swapping to a positive one), often oblique to those defined by the LM qtzD granulites, are compatible with progressive accumulation of an assemblage dominated by Mg-rich, Fe–Ca-poor pyroxene.

Pyroxenites (~ phlogopite) with alternative predominance of high-Ca Cpx or enstatite occur as small (~<0.5 m across) enclaves. They seem to represent magmatic cumulates crystallized from, and later captured by, a basic magma parental to the granulites LM qtzD.

(2) Two-pyroxene tonalitic granulites (LM to) are foliated finer-grained pyroxene–biotite rocks with min-
eral assemblage Opx–Cpx–Bt–Pl–Qtz (± Kfs, Amf); Ilm, Ap and Zrn are common accessories. High-Ca pyroxene contains fine lamellae of orthopyroxene; primary Opx is often absent. The tonalitic granulites form no larger coherent unit but occur sporadically throughout the LGM, in particular in layered sequences.

The granulites LM to are metaluminous (A/CKN = 0.78–0.98) with K2O/Na2O ratios normally lower than unity (mean = 0.67). They contain in general the highest SREE with moderately LREE-enriched patterns (Ce*/Yb* = 3.7–7.9) and pronounced negative Eu anomalies (Eu/Eu* = 0.50–0.62). The isotopic signature is significantly more evolved both in neodymium (εNd = −5.2 to −5.3) as well as strontium (εSr = 0.70854 and 0.71027) than in the case of the group LM qzD. The considerably more radiogenic Sr of the latter sample seems to reflect its retrogression to foliated Amf–Bt tonalitic gneiss.

(3) Opx–Grt charnockites (LF ch) of granitic–granodioritic composition, including fine-grained, unfoluted rock types, form not only tabular to podiform bodies, up to 300 m long, but also thin layers in layered sequences (Rudolfov). Estimated modal composition of the sample Li-5 is Qtz 35 vol. %, Pl (An25–27) 34 %, mesoperthite 25 %, Opx 5 %, Alm-rich Grt 1 %; Ilm, Ap and Zrn are the main accessories. Granular mosaic of the rock-forming minerals indicates equilibrated assemblage. The Fe-rich Opx (Fs ~ 70 mol. %) is strongly pleochroic, X: red brown, Y: beige, Z: bluish green.

The rather siliceous (SiO2 = 72.2–75.2 %) charnockites are saturated in alumina (A/CKN = 0.96–1.1, mean 1.05). The sample Li-5 has a relatively flat REE pattern (Ce*/Yb* = 2.9) with a deep negative Eu anomaly (Eu/Eu* = 0.39). Its strontium isotopic composition is intermediate between the groups LM to and LF gr (εSr = 0.71614), while its Nd isotopic signature is practically undistinguishable from the tonalitic granulites (εNd = −5.4). Grt–Opx–Pl barometry indicates crystallization at moderate pressures (c. 5 kbar).

(4) Felsic Grt (± Bt) granulites (LF gr) predominate within the LGM (>70 vol. %). Apart from rare relict domains preserving massive texture and primary HT mineralogy, most of them were mylonitized and recrystallized to foliated varieties with platy quartz and fine-grained feldspar mosaic. Modal composition (Li-6): mesoperthite 50 %, Qtz 39 %, Pl 5 %, Alm-rich Grt 4 %. Accessories are Mt, Ap, Zrn and acicular Rtl. Mesoperthite is made of about equal proportions of Kfs and Na-oligoclase.

The granulites LF gr are silica- and K-rich (SiO2 = 75.0–79.6 %, K2O/Na2O = 1.0–2.4), mainly slightly peraluminous rocks (A/CKN = 0.95–1.20). The only limited excess of alumina accounts for the absence of alumosilicates (Vrána – Jakeš 1982). The sample Li-6 has a REE pattern with the lowest LREE enrichment (Ce*/Yb* = 2.1) and a huge negative Eu anomaly (Eu/Eu* < 0.16). As shown by Valbracht et al. (1994) and our results, the granulites LF gr contain a highly radiogenic strontium (εSr = 0.73042 and 0.72990) and their Nd isotopic composition overlaps with the previous groups (εNd = −4.2 to −5.4).

The granulites LF gr are thought to have crystallized at moderate pressures (c. 5 kbar) as an anhydrous assemblage of quartz and ternary feldspar (Or15–20,Th15–20) with garnet (XGt ~ 0.04), minor plagioclase, and Fe–Ti oxide. The Fe–Ti oxide is characterized by Mt–Ilm intergrowths indicating unmixing accompanied by oxidation of former ulvospinel (implying high T and low water activity during the primary crystallization of acid Lišov granulites).