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

V. JANOUŠEK1 – S. VRÁNA2 – F. FINGER3

1Institut für Mineralogie, Universität Salzburg, Austria, vojtech.janousek@sbg.ac.at
2Czech Geological Survey, Prague, Czech Republic, vrana@cgu.cz

The Gföhl 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 (LGM) E of České Budějovice (S Bohemia) shows major differences from the neighbouring granite bodies (e.g., the Blanský les Massif) (Vajner 1964; Vrána – Jakš 1982; Vrána 1990; Kotková 1998; Janoušek – 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 charnockites);
(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 Bree mention et al. 1982) that is in line with the established age of the granulate-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 Zvětov, in the E of the Lišov mass. These are finer-grained, foliated rocks with mineral assemblage Opn–Cpx–Bt; Pl; Qtz (± Kfs, Amf, Grt); Ilm, Ap and Zrn are common accessories. Pyroxenites together with Bt and Pl occur in an equilibrated granular molar texture. High-Ca pyroxene is light grey-green, nearly non-pleochroic, 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 (Ce0/Yb0 = 5.8–6.4) with slight negative Eu anomalies (Eu/Eu* = 0.80–0.86). The analysed two samples are isotopically the most primitive ([68Sr/66Sr]0 = 0.7063 and 0.7067, 87Sr/86Sr = 0.116 and –2.4).

The modally layered sequences (e.g., Rudolfov) 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 Amf–Pl assemblage, ± pyroxene.

The rare Gt-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 (Ce0/Yb0 = 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 Zm 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/CNK = 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 (Ce₆/Yb₆ = 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 (ε⁴⁰⁰Nd = −5.2 to −5.3) as well as strontium (⁸⁷Sr/⁸⁶Sr₀ = 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 granite–granodioritic composition, including fine-grained, unfoliated 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 (An₃₅₃₇) 34 %, mesoperthite 25 %, Opx 5 %, Alm-rich Grt 1 %; Ilm, Ap and Zm 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/CNK = 0.96–1.10, mean 1.05). The sample Li-5 has a relatively flat REE pattern (Ce₆/Yb₆ = 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 (⁸⁷Sr/⁸⁶Sr₀ = 0.71614), while its Nd isotopic signature is practically undistinguishable from the tonalitic granulites (ε⁴⁰⁰Nd = −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, Zm 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/CNK = 0.95–1.20). The only limited excess of alumina accounts for the absence of aluminosilicates (Vrána – Jakeš 1982). The sample Li-6 has a REE pattern with the lowest LREE enrichment (Ce₆/Yb₆ = 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 (⁸⁷Sr/⁸⁶Sr₀ = 0.73042 and 0.72990) and their Nd isotopic composition overlaps with the previous groups (ε⁴⁰⁰Nd = −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 (Or₆₄ Ab₁₂ An₂₆) with garnet (X₆ = 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).