Garnet-Bearing Mafic Granulites from the Lišov Granulite Massif

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Intermediate and basic granulites, although subordinate in the south Bohemian granulite bodies, represent important rock types for reconstruction of P-T evolution of these bodies. In the Lišov granulite massif, borehole LV1 situated south of Lišov provides a unique fresh material of this kind. The rocks display cm to dm-scale compositional banding, with predominance of granulites of dioritic to gabbroid composition. Relatively abundant are garnet-bearing mafic granulites, in which garnet (up to 5mm in size) has been partially preserved. Garnets feature homogeneous cores containing up to 34 vol. % Prp and 20 vol. % Grs, and $X_{Ca} + X_{Mg}$ decrease along with $X_{Fe} + X_{Mn}$ increase in about 200 m wide rim zone. This kind of zoning and widespread reaction textures are consistent with operation of decompression reactions Grt + Cpx + Qtz = Opx + Pl and Grt + Cpx = Opx + Pl + Spi. These reactions produce Opx+Pl±S_{pi} symplectites around garnet or even results in its complete consumption.

Adjacent to domains with relic garnet, orthopyroxene-plagioclase clinopyroxene pargasitic hornblende mineral assemblage with equilibrium polygonal mosaic texture occurs. Opx and Cpx grains in the two-pyroxene granulites are homogeneous, and Opx composition is similar to that of the symplectite Opx. Observed decompressional textures along with presence of Al-Na-enriched clinopyroxene inclusions in garnet are consistent with a high-pressure stage of the granulite evolution, pre-dating formation of the medium-pressure two-pyroxene granulites in the Lišov massif. Preliminary results of Grt-Cpx and Grt-Cpx-Pl-Q geothermobarometry indicate minimum P-T conditions of 910°C and 13 kb for this high-pressure stage.

Contribution to the Problem of Alpine Tectono-Metamorphic Overprint in the Southern Veporicum Basement (Inner Western Carpathians)

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The southern Veporicum underwent the strongest Alpine tectono-metamorphism of the three basic Inner Western Carpathian units (Tatricum, Veporicum and Gemericum). Inasmuch as no indicative metamorphic mineral assemblages have been found in the clastic beds of the Veporicum Mesozoic cover, we concentrated on the variety of mineral reactions, reflected in the polymetamorphosed basement rocks.

Metamorphic overprinting is illustrated by common replacements of the pre-Alpine metamorphic assemblages consisting of porphyroblasts of, e. g., micas, plagioclase, garnet, staurolite. The newly formed metamorphic assemblages (in metapelites: phyllosilicates, tiny garnet of grossularite-almandine composition, chloritoide and scarcely kyanite, staurolite and amphibole of tschermakitic composition) are of the Barrovian type and are supposed to be associated with an increased geothermal gradient. The Alpine reworking of the basement is largely controlled by open-system reactions which show a late-syn- to post-kinematic character. The principal sources of Alpine regional metamorphism stem from a deep reactivation of the basement during which the fluid and thermal circulation increased. The use of phengitic muscovite and/or in grossularite component enriched garnet for geothermobarometric purposes is discussed and there are outlined some pitfalls in a uniform interpretation in case of polymetamorphosed or weakly metamorphosed rocks. The composition of phengitic muscovites show a strong dependence on bulk rock geochemistry (especially on the Al_2O_3 content) and the negative correlation between the Na (respectively $Al_{tot.}$) and K (and/or Si along with an increase of FM) per s.f. is documented, too. The Alpine alterations are at a more local scale characterised also by the transformation of a granitic rock to kyanite - Mg-chlorite schist in the process of Mg-metasomatism which is envisaged synchronous with formation of talc on expense of magnesite. These fluid-assisted metamorphic reactions are closely linked with the mobility of Al_2O_3. Conditions of the Alpine regional metamorphism are estimated with caution at temperatures between 350°C and 500°C and under lower to middle pressure (2.5-4.5 kb).

Four $^{40}Ar/^{39}Ar$ spectra of the newly formed amphiboles from the metapelites, which fall within a range of 105--115 Ma, presumably reflect the onset of the Alpine regional metamorphism (weak synkinematic recrystallisation). This may reflect collision of the Veporicum with the Gemericum marked by linear deformation fabrics which could be related to "extension parallel with the orogen". The relative second metamorphic event is the studied Barrovian late-syn- to postkinematic recrystallisation, which might have taken place due to post-thickening relaxation. Many data (predominately muscovites) cluster within a narrow time span of ca. 86-88 (85-89) Ma. This indicates an accelerating uplift and probably fast unroofing which was to a certain degree associated with propagation of recrystallisation. Unroofing was probably followed by thrus-

ting of the higher Mesozoic nappes which were emplaced in a relatively short time and in a "thin skinned" tectonic regime. During the time span of 75 Ma to 80 Ma a temperature of about 300°C was sustained in certain parts of the southern Veporicum, as documented by biotite cooling ages. This Late Cretaceous period is characterised by an extensional regime and by local thermal perturbation. A thermal effect of a contact aureole near the Rochovce granite may be regarded as the third episode of the Alpine metamorphic history. We interpret some older age (e.g. a staircase spectra of muscovite - 123 Ma and 134 Ma) as a result of Alpine excess Ar. On the other hand, amphiboles from metabasics recording 137 Ma and 150 Ma reflect an incomplete Alpine rejuvenation of the Hercynian metamorphism.

The petrographic phenomena as well as geochronological data indicate an increase in Alpine thermal reworking from the southwest to the northeast. The Cretaceous orogenetic evolution of the southern Veporic domain had many features in common with the Mittelostalpin unit in the Eastern Alps but a potential pre-Barrovian HP event (of a different provenance than that of the southerly situated Meliaticum) has not been revealed.

High Pressure – Low Temperature Metamorphism in the West Sudetes: Tectonic Implications

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High pressure – low temperature (HP-LT) metamorphic rocks (blueschist facies) are an important tool in the construction of tectonic models, as they are, commonly, interpreted to delineate major tectonic sutures. In the West Sudetes, blueschist facies metamorphism is recorded in two areas: (a) the E and S metamorphic envelope of the Karkonosze pluton (Cháb and Vrána 1979, Kryza and Mazur 1995, Smulikowski 1995, Patočka et al. 1996) and (b) the Kaczawa complex (Kryza et al. 1990, Muszyński and Kryza 1993).

The southern and eastern envelope of the Karkonosze granite comprises several tectonic units which differ in their lithostratigraphic contents and P-T paths (Kryza and Mazur 1995, Mazur 1995). The blueschist facies mineralogy (e.g. glaucophane, Si-rich phengite) is found in the external and structurally highest tectonic units (Niedamirów, Rýchory and Železný Brod areas) and is best preserved in metabasic rocks associated with phyllites of poorly constrained, early- to mid Palaeozoic age (including documented Silurian). The P-T conditions for the HP event are estimated at ca. > 8 kbar and 300-400°C. The P-T paths of these HP units are in marked contrast with the conditions experienced by the structurally underlying tectonic unit (the Kowary/Izera gneisses and their mica schist envelope) which underwent MP regional and, locally, contact metamorphism. The HP rocks are separated from the underlying tectonic unit by a tectonic contact (Mazur 1995).

The Kaczawa complex comprises several tectonic units interpreted as thrust sheets, involving fragments of Palaeozoic succession (Cambrian to Upper Devonian and, locally Lower Carboniferous), and polygenic melange bodies mostly assumed to be Upper Devonian or Lower Carboniferous in age (Baranowski et al. 1990). In spite of deformation and metamorphism, primary sedimentary and volcanic structures are well preserved in the Kaczawa complex rocks. A record of early HP-LT metamorphic event has been found in most of the tectonic units of the area and it includes: (a) zoned amphiboles in mafic rocks (from glaucophane to actinolite); (b) zoned white mica (Si content from 3.55 in cores to 3.05 in rims); and (c) relics of pure jadeite in felsic metavolcanics. The P-T conditions of the HP-LT event can be assessed as > 10 kbar and 300-400°C. The medium pressure overprint generally represents conditions typical of lower part of the greenschist facies.

Tectonic implications

1. The two described metamorphic complexes in the West Sudetes (E and S Karkonosze and Kaczawa complex) bear record of early HP-LT events typical of the blueschist facies, followed by MP metamorphism, mostly under the greenschist facies. As shown by ^{40}Ar-^{39}Ar dating (Maluski and Patočka 1997), which is also supported by geological constraints, the HP event took place at ca. 360 Ma, while the MP overprint can be dated at around 340 Ma ago.
2. The presence of blueschist facies rocks corroborates the hypothesis that this part of the Sudetes may represent fragments of a Variscan accretionary prism (Baranowski et al. 1990). In a broad sense, the area is located at the boundary between major tectonic zones of the Variscan orogen: Saxothuringian to NW, and Barrandian plus Moldanubian to SE.
3. The general metamorphic zonation in the Sudetes allows a subdivision of this area into two domains: (a) WNW domain, with records of HP-LT metamorphism, and (b) ESE domain, with relics of UHP-HT rocks and usually strong LP-HT regional imprint. Following the interpretation based on "extrusive tectonics" models (Thompson et al. 1997), the first domain may comprise fragments of narrow, moderately buried (ca. 30 km) and quickly exhumed external parts of the orogen, while the second domain could be a fragment of deeply buried (50 or more km) and rather slowly exhumed internal parts of the Variscan belt.
4. Detailed tectonic interpretations remain controversial. The two blueschist facies complexes, apart from their similarities, display important differences.

E and S Karkonosze: HP-LT rocks are found only in the upper tectonic units, on the E and S(?) side of the so called Leszczyniec Shear Zone. Such a position of the blueschist facies rocks confirms that this zone is a major tectonic boundary.

Kaczawa complex: in spite of its mosaic tectonic pattern – it seems to represent a roughly coherent stratigraphic sequence which as a whole experienced roughly the same P-T conditions. The recognised close spatial association of the HP rocks and polygenic melange bodies suggests that the model of "imbricated slab" or "subduction channel" could have been the mechanism of exhumation of this rock complex.

These differences seem to be at variance with the new concept of Cymerman et al. (1997) which assumes a continu-