A Mechanism for Syn-Convergent Exhumation of HP Granulites in the Bohemian Massif, Czech Republic: Geochronological, Structural and Petrological Constraints

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We examined the structural and metamorphic evolution around the HP granulite belt at the NE margin of the Bohemian Massif in order to understand the mechanism of exhumation of HP rocks within the orogenic root domain.

The granulite belt and adjacent migmatitic orthogneisses show homogeneous vertical fabric developed in the thickened lower crust under HP granulite facies conditions (~18 kb/800 °C). The vertical fabric was later reworked by shear zones, which make a positive fan–like structure around the HP granulite belt. The assemblages associated to the second structure indicate its formation in the middle crust under amphibolite facies conditions (~10 kbar/700 °C). The AMS study performed on the macroscopically near-isotropic granulites and retrograde granulitic gneisses confirmed the vertical fabric and revealed the existence of a horizontal lineation associated with them. On the west- and east-dipping magnetic foliations associated with symmetric fan formation, the lineations are E-W plunging. These observations may be interpreted in terms of strain partitioning in pure shear dominated transpression, where frontal convergence is accommodated by thrust zones with their shearing direction almost perpendicular to the boundaries of the granulite belt.

Study of nearby metasedimentary belt shows similar structural succession, but developed under different conditions. First structure is vertical and associated to the assamblage ky-st-grt-bt indicating maximum burial depth of 10 kbar and 650 °C. Widespread folding resulted into subhorizontal fabric overprinting the early steep fabric. Formation of subhorizontal foliation is associated with sill-grt-bt indicating the decompression to 8 kbar at 650 °C.

These observations indicate that in the first stage of E-W compression the rocks of the root absorbed most of the pure shear deformation and thickening which resulted in the vertical N-S trending fabric developed in all crustal levels. Further shortening led to the vertical extrusion of the HP lower crustal rocks along a narrow vertical channel. Vertical extrusion results partly into lateral symmetrical thrusting of lower crustal material over adjacent middle crustal rocks. Our study shows that this type of exhumation of HP rocks is differential and may bring only small portions of HP lower crust adjacent to the middle crustal rocks, which never experienced the HP stage. We conclude that as this extrusion stage is associated with a mechanical collapse of the early vertical fabric into subhorizontal structure, the early structures responsible for the exhumation of HP rocks in similar cases are likely to be highly obliterated.

Quantitative Textural and Microstructural Study of Orthogneiss Deformed during Continental Underthrusting

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Microstructures and textures of feldspars and quartz from naturally deformed orthogneiss were investigated from a nappe pile showing inverted Barrovian metamorphic zoning at the eastern margin of the Bohemian Massif. This study was carried out through detailed microstructural and textural work combined with modelling of metamorphic equilibria using pseudosections in Thermocalc software. The PT conditions were estimated using average P-T method, which allowed to correlate microstructural and textural evolution of orthogneiss sheets with metamorphic zonation of adjacent metapelites. The quantitative textural analysis was applied to 40 orthogneiss samples from three metamorphic zones characterized by peak temperatures varying from 500 to 650 °C. The statistical microstructural analysis included study of grain-size distribution, planimetry, grain shape and grain boundaries preferred orientation and grain contact frequency analysis. The crystal preferred orientation (CPO) of all mineral phases from all metamorphic zones was determined using the EBSD in automatic and manual mode

Characteristic feature is a very low CPO of plagioclase in all studied samples showing dominant activity of <010>(001) a <010>(100) slip systems. Quartz exhibits low and intermediate fabric intensities with combined activity of rhomb<a> a rhomb<c> slips in high-grade gneisses and dominant basal

<a> slip in low-grade rocks. K-feldspar shows strong CPO in high-grade rocks associated with activity of <010>(001) or <100>(001) slip systems. The K-feldspar in low-grade exhibits very low fabric intensity and combined activity of several slip systems <010>(001), <100>(001) a <100>(010).

The grain-size analysis shows continuous increase of median grain size and grain size spread with increasing metamorphic grade. The grain contact frequency method indicates progressive increase in regular distribution towards higher metamorphic grades. In addition, the orientation tensor analysis of grain boundaries indicates systematic decrease of anisotropy of mineral fabric with increasing metamorphic grade. Recrystallized feldspars show high axial ratios, strong shape preferred orientation and strong CPO over the whole range of metamorphic grades suggesting important contribution of dislocation creep. The CSD analysis suggests increasing importance of grain growth rate and decreasing production of new nuclei with increasing metamorphism. In contrast, the recrystallized quartz shows highest degree of solid state annealing and absence of shape preferred orientation for the lowest metamorphic grade. This is associated with significantly higher quartz grain size with respect to that of plagioclase. The shape preferred orientation and elongation of quartz increases with metamorphic grade, which is also connected with unification of quartz and plagioclase grain sizes.

All these data show increasing rheological role of quartz with increasing metamorphic grade. The recrystallized feldspars, which are weak at low grades are accommodating less viscous deformation with progressive deformation. The strain partitioning between individual phases typical of lower metamorphic grades is diminishing with increasing temperature and the deformation becomes homogeneously distributed throughout the whole volume of rock. We note, that rheology of continetal crust is dominated by feldspar minerals at lower crustal levels and by quartz in deeper crust but only for particular ratio of temperature increase and velocity of continental underthrusting that is typically developed in continental underthrusting regimes.

Metamorphic Record in the Metasediments from the Bystrzyckie Mts., West Sudetes

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The Orlica-Śnieżnik dome is situated in the easternmost part of West Sudetes. The western part of the dome, called the Bystrzyckie Mts., comprises a large orthogneiss body (the Śnieżnik orthogneiss) mantled by rocks of the Stronie Formation. The latter includes mainly mica schists, paragneisses, basic and acid metavolcanics and marbles. The orthogneiss represents deformed and metamorphosed granitic body dated at 495–515 Ma using single-zircon evaporation and SHRIMP method (Kröner et al., 2001). The Stronie Formation, originally forming metasedimentary cover of the orthogneiss protolith, is believed to be of Late Proterozoic or Early Paleozoic age on the basis of micropaleontological finds (Gunia and Wierzchołowski 1979).

In the Bystrzyckie Mts., rocks of the Stronie Formation form four separate outcrops described by Dumicz (1964) as individual tectonic units. From the NE to SW and from bottom to top of the structural sequence, these are: Równia Łomnicka, Mostowice-Jagodna, Gniewoszów-Kamieńczyk and Niemojów-Czerwony Strumień units. Their rocks recorded a sequence of five deformation events (Szczepański, 2001). The oldest D_1 structures are represented by the S_1 foliation preserved as inclusion trails mainly within plagioclase blasts. Subsequently, the S_1 foliation was deformed by F_2 isoclinal folds. The new S_2 foliation developed parallel to axial planes of these folds. The next, D_3 episode was connected to a top-to-the-south non-coaxial shearing probably associated with thrust tectonics. The following D_4 deformation involved regional-scale folding which produced east-vergent F_4 folds. Finally, east–west-trending F_5 kink-folds were formed by a brittle-ductile deformation at a shallow crustal level.

Metasediments of the structurally lowermost Równia Łomnicka unit underwent greenschist-facies metamorphism. Peak temperatures calculated for these rocks range between 513–548 °C using the garnet-biotite and garnet-muscovite geothermometers. The maximum pressures estimated with Grt-Pl-Ms-Bt geobarometer reach values of 7.2–9.8 kbar. Similar pressures in the range of 7.1–8.1 kbar were estimated using phengite geobarometer. These peak metamorphic conditions were probably achieved during the D_2 deformation event. In the Gniewoszów-Kamieńczyk unit, overlying the Równia Łomnicka unit, peak mineral assemblages are related to the D_3 episode and form a typical Barrovian-type sequence with biotite, garnet and staurolite zones. The garnet-biotite, garnet-muscovite and plagioclase-muscovite geothermometers produced values of 465 °C for biotite zone, 572–587 °C for garnet zone and 638 °C for staurolite zone. The phengite geobarometer yielded pressure of 4.8–6.1 kbar. Finally, metasediments from the structurally uppermost Niemojów-Czerwony Strumień unit experienced amphibolite-facies metamorphism. Peak temperatures calculated for mineral assemblages defining the D_3 structures in these rocks using garnet-biotite and garnet-muscovite geothermometers are scattered in the range of 613–653 °C. Pressures of 5.9 kbar were calculated using the phengite geobarometer for the same rocks.