<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.

Summing up, the tectonic units comprised in the Bystrzyckie Mts. recorded different metamorphic conditions. These can be generally characterized as relatively HP/LT for the structurally lowermost Równia Łomnicka unit and MP/MT for the Gniewoszów-Kamieńczyk unit and the structurally uppermost Niemojów-Czerwony Strumień unit. This implies that they may represent individual thrust sheets which underwent different P-T paths. Consequently, it is suggested that the whole Bystrzyckie Mts. represent a pile of nappes showing tectonically inverted metamorphic zoning. This inversion of metamorphic gradient was most probably achieved during the D_3 tectonic episode under a transpressive regime. It was possibly associated with the dextral strike-slip displacement along the contact of the Teplá–Barrandian and Moldanubian terranes, postulated by Aleksandrowski et al. (2003).

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References

ALEKSANDROWSKI P., MAZUR St. and SZCZEPAŃSKI J., 2003. The Tepla-Barrandian / Moldanubian Terrane boundary in the Orlica Mountains, Central Sudetes, NE Bohemian Massif: structural and petrological evidence.

DUMICZ M., 1964. Geology of the crystalline massif of the Bystrzyckie Mts. *Geol. Sudetica*, 1: 169-208.

GUNIA T. and WIERZCHOŁOWSKI B., 1979. Microfossils from the quartzitic schists in vicinity of Goszów, Śnieżnik Kłodzki Massif, Central Sudetes. *Geol. Sudetica*, 14: 8-25.

KRÖNER A., JAECKEL P., HEGNER E. and OPLETAL M., 2001. Single zircon ages and whole-rock Nd isotopic systematics of early Palaeozoic granitoid gneisses from the Czech and Polish Sudetes (Jizerské hory, Krkonose Mountains and Orlice-Snezník Complex). International *J. Earth Sci.*, 90: 304-324.

SZCZEPAŃSKI J., 2001. Multiphase deformation of orthogneiss and enveloping schists in the southern part of the Bystrzyckie Mts, Orlica-Śnieznik Dome, West Sudetes. *Min. Soc. Spec. Pap.*, 19: 165-167.

The Role of Zinc in Stabilization of Spinel-Bearing Mineral Assemblages – Examples from the Bohemian Massif and NW Namibia

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Spinels are chemically diverse minerals found in many igneous and metamorphic rocks, and spinel-bearing mineral equilibria are considered as important indicators of physical conditions of metamorphism. Chemical composition of spinels in metasedimentary and acid meta-igneous granulite-facies rocks usually approaches Fe-rich members of the spinel ($MgAl_2O_4$) – hercynite ($FeAl_2O_4$) solid solution. Important minor constituents expanding the spinel stability field are represented by Fe^{3+} (magnetite), Ti (ulvöspinel) and Zn (gahnite) components (White, 2002; Harley, 1989; Carswell, 1993). The stability field of spinel is expected to expand also with increasing fO_2, which probably leads to an inversion of topology in the petrogenetic grid, where the invariant points [spinel] and [sillimanite] are stable at low oxygen fugacity, and [sapphirine], [garnet] and [cordierite] points are stable at high oxygen fugacity (Hensen, 1986; Powell, 1988). Petrogenetic grids in the extended KFMASHTO system have already been constructed (Clarke, 1989; White, 2002) providing important constrains on the influence of TiO_2 and Fe_2O_3 on spinel and biotite-bearing equilibria.

Zn content in spinel composition causes a similar topological inversion. The gahnite component can stabilize this phase to lower temperatures and higher pressures, which has been demonstrated by several experimental works (Hensen, 1986; Shulters, 1989; Nichols, 1992). Samples of spinel-bearing acid granulites from the Bohemian Massif (the Strazek Moldanubicum) and from the Neo-Proterozoic Kaoko belt of NW Namibia were chosen to test the influence of gahnitic component on the spinel stability field. In samples from the Bohemian Massif, hercynite crystals were observed rimming metastable kyanite crystals, probably as a result of local equlilibrium between Grt and newly formed Sill. In several cases, Hc was observed in association with Bt. Samples from NW Namibia also show the stable mineral assemblage Grt-Sill-Hc-Bt. In all samples, the spinels correspond to spinel-hercynite-gahnite solid solution with moderate (0.05–0.09 pfu.) to high (0.08–0.18 pfu.) Zn content, and the X_{Mg} values in the range of 0.046–0.098 and of 0.07–0.10, respectively. The amount of Fe^{3+}, (e,g, the magnetite component) was estimated using stoichiometric constrains and its content is 0.03–0.05 pfu for the Bohemian Massif samples and 0.01–0.07 pfu for the samples from Namibia. The amount of Ti is negligible in both cases.

The PT conditions of equilibration of the mineral assemblage Grt-Sill-Hc-Bt were calculated using the software VERTEX (Connolly, 1990). In order to model the expansion of the stability field of the spinel-bearing assemblages, the thermodynamic data for the gahnite end-member (Dessureault, 1994) were incorporated in the dataset of Holland and Powell (1998). Simple mixing model for spinel-hercynite-gahnite end-mem-