Quantitative textural and microstructural study of orthogneiss deformed during continental underthrusting: result of contrasting mineral rheologies and solid state annealing

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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 zones at the eastern margin of the Bohemian Massif. This was carried out through detailed microstructural and textural work combined with modelling of metamorphic equilibria using pseudosections via the Thermocalc software. The PT conditions were estimated using the average P-T method, which allowed a correlation of the microstructural and textural evolution of orthogneiss sheets with the metamorphic zonation of adjacent metapelites. The temperature evolution of individual thrust sheets is interpreted to result from a process of continental underthrusting associated with a continuous and slow temperature increase. The quantitative textural analysis was applied to 40 orthogneiss samples from three metamorphic zones characterised by peak temperatures varying from 500 to 650 °C. The SEM backscatter images have been recorded with a Camscan electron microscope and digitised for image analysis. The above procedure was carried out in the ArcView GIS environment in order to maintain the correct topology of grain boundaries. The grains (polygons) and grain boundaries (polylines) defined in Arc View, have been imported into MATLAB where the statistical manipulation and calculation was performed using the PolyLX toolbox (Lexa, 2000). This analysis included the study of grain size distribution, planimetry, grain shape and grain boundary preferred orientation and grain contact frequency analysis. The results of orientation analysis were expressed using rose diagrams and Rf/f diagrams. Measured crystal size distributions (CSD) were used to discuss the kinetics and dynamics of crystallization. The crystallographic preferred orientation of all mineral phases from all metamorphic zones was determined using EBSD in automatic and manual mode

A characteristic feature is a very low crystallographic preferred orientation of plagioclase in all studied samples which shows dominant activity of <010>(001) a <010>(100) slip systems. Quartz exhibits low and intermediate fabric intensities with combined activity of rhomb<a> and rhomb<c> slips in high grade gneisses and dominant basal <a> slip in low grade rocks. K feldspar shows strong crystallographic preferred orientation 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 probability plots of grain size distributions show that in all studied samples the grain size distributions can be best described by lognormal distribution. The grain size analysis shows continuous increase of median grain size and grain size spread with increasing metamorphic grade. The grain contact frequency method show a progressive increase in regular distribution towards higher metamorphic grades. The orientation tensor analysis of grain boundaries indicates a 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 log normal plots show increasing grain size and a growing contribution of solid state annealing with increasing metamorphic grade for low to medium grades only. The CSD analysis suggests an increasing importance of grain growth rate and decreasing production of new nuclei with increasing metamorphism. In contrast, recrystallized quartz shows the highest degree of solid state annealing and an absence of shape-preferred orientation for lowermost 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 the increasing rheological role of quartz with increasing metamorphic grade. The recrystallised feldspars, which are weak in low grades are accommodating less viscous deformation with progressive deformation. The strain partitioning between individual phases typical for lower metamorphic grades is diminishing with increasing temperature and deformation becomes homogeneously distributed over the whole volume of rock. We note that the rheology of continental crust is dominated by feldspar minerals in lower crustal levels and by quartz in deeper crust but only for particular ratios of temperature increase and velocity of continental underthrusting.