for complex evaluation of composite magmatic systems. In the present study, we focus on physical processes operating along internal boundaries between individual magma pulses in a magmatic system, evolving from early sheeting to younger nested diapirs (Tuolumne Batholith, central Sierra Nevada, USA) and we show that structures preserved along internal contacts may record information about the rheological state of juxtaposed magma batches, complex flow along these boundaries, and late fabric formation during emplacement of progressively younger magma pulses and regional tectonic strain.

The Tuolumne Batholith is a large composite batholith exposed in the central Sierra Nevada (California, USA), emplaced as a nested diapir during Late Cretaceous into low-grade metasedimentary and metavolcanic rocks and older plutons. Succesive emplacement of four main units making up the batholith (Kuna Crest, Half Dome and Cathedral Peak granodiorites, Johnson granite porphyry) produced concentric array of internal contacts between compositional domains. In detail, however, internal contacts and associated igneous features vary widely, from simple sharp or gradational contacts, sheeted domains, to very complex zones of mingling and flow. We discovered several domains of very complex magma mingling and flow in the eastern part of the Tuolumne Batholith, typically asocciated with geometric irregularities and deflections of the contact. These domains are characterized by the presence of complex magma mingling, complicated schlieren patterns, disequilibrium microstructures, multiple magmatic sheets, gravitational instabilities and physical accummulations of K-feldspar megacrysts. Four distinct magmatic fabrics are developed in this domain, two of which occur throughout the Tuolumne Batholith. The two earliest fabrics record strain during flow in pulses. A slightly younger NNW-SSE foliation is typically parallel to internal contacts, whereas the youngest WNW-ESE foliation runs across all internal contacts and overprints older magmatic features. Both the regionally developed foliations share a single steeply plunging magmatic lineation, defined by identical igneous minerals. These multiple magmatic fabrics record a temporal evolution of strain caused by flow during chamber construction to tectonic strain of a relatively static chambers.

Based on our field research, we reached the following conclusions: (i) simple gradational zones between two juxtaposed magma batches represent stable contacts allowing partial homogenization of magma pulses within transition zones and implying slower rates of interactions and small rheological contrasts; (ii) zones of complex magma mingling and flow, often displaying complex, but ordered patterns, develop due to multiple gradients introduced to the system during emplacement of magma surges along wall-rock irregularities; (iii) internal emplacement mechanisms recorded in domains along internal contacts in the Tuolumne Batholith involve multiple rheology-dependent processes, e.g. magma escape flow and shortening in magmatic stage, negative volume change of cooling magmas along margins with progressive accummulation of outward-younging sheets and thermal fracturing and magmatic stoping of older solidified magmas; (iv) The presence of internal contacts and spatial distribution of other igneous structures in the Tuolumne Batholith are in contrast with chamber-wide convection models, we argue for small-scale convective structures operating during final stages of magma chamber construction; (v) overprinting relationships show that the youngest WNW-ESE magmatic fabrics formed after chamber construction and represent late increments of regional tectonic strain. We emphasize that physicochemical gradients across the contact, relative rheology of juxtaposed magma pulses, geometry and spatial orientation of the interface and temporal evolution of the system, are the most important factors controlling the nature of processes along internal boundaries in magma chambers. In addition, our study provides some field constrains on dynamic forward modelling work (Bergantz, 2000) predicting the geometry of interface between juxtaposed magma pulses for various rheologies and geometries of the modelled system.

References

BERGANTZ G., 2000. On the dynamics of magma mixing by reintrusion: implications for pluton assembly processes. *Journal of Structural Geology*, 22: 1297-1309.

Quartz and Feldspar Rheology Contrasts under Natural Thermal and Strain Gradients: A Comparative Study

Prokop ZÁVADA, Karel SCHULMANN, Ondrej LEXA and Jiří KONOPÁSEK

Institute of Petrology and Structural Geology, Charles University, Albertov 6, 128 43, Prague

Existing models of crustal rheology use experimentaly derived flow laws described by constitutive equations, which are established for minerals such as plagioclase or monomineralic rocks like quartzites, marbles. However, the crust is commonly composed of polyphase rocks – namely granitoids, represented by mixtures of felsic minerals of different proportions, variable grain shape and grain-size distribution. Detailed microstructural observations, textural analysis and EBSD measurements were used to estimate relative changes in strain partitioning and point to inconstant 'relative viscosity' under different thermal conditions and strain intensities. The study was carried out at three paleothermal levels:

1) Neoproterozoic para-autochtohnous metagranitoids reworked at conditions corresponding to amphibolite facies
2) "Lower crystalline unit" (LCU) is a thrust sheet composed of porphyritic orthogneisses metamorphosed at conditions equal to ca 600 °C at 14 kbar.
3) "Upper crystalline nappe" (UCU) formed by high temperature orthogneiss that contains inclusions of high-pressure granulites metamorphosed at ca 750-800 °C and 15-17 kbar.

The parent rock – porphyritic metagranitoids in heterogeneously deformed piles have similar initial grain-size distributions, space positions and phase fractions (23% K-feldspar, 30% plagioclase and 35% quartz). The shapes of individual mineral phases were traced from photographs. Rxz as well as Ryz values have been estimated using modified Rf/ϕ method based on incremental destraining of elliptical objects (Lisle, 1993). The average deformation was calculated from area weighted strain values. The calculated data were plotted in Flinn diagram where individual constituent phases from each sample were connected by tie lines with a circle representing bulk strain value. K-feldspar appears as a stronger mineral in the LCU orthogneiss, whereas quartz and plagioclase show higher strain intensities. Shapes of strain ellipsoids for each mineral show narrow span in Flinn's diagram. This span widens in samples with higher bulk strain intensity. High deformation intensity is accompanied with a switch in relative deformability, so that quartz becomes stronger than K-feldspar. In moderately deformed UPU orthogneiss quartz shows very low strain intensities, while feldspars are deformed more intensely. The shapes of strain ellipsoids are prolate and closer to each other in high bulk strain intensity sample. This suggests that quartz becomes more deformed, while feldspars contribute to the bulk strain less significantly than in moderately deformed sample. These data are also presented in diagram of bulk strain against ratios of strain intensities of individual minerals for the given sample, which are expressed using Ramsay's D value, $D=[(Rxy)^2+(Ryz)^2)]^{1/2})$. Highest strain ratios are achieved between D_{Kf}/D_{qtz} and D_{plg}/D_{qtz} for low strain intensities in high-grade orthogneisses. Relatively weak D_{kf}/D_{plg} ratio suggests similar yielding of both mineral phases. However, D_{Kf}/D_{qtz} and D_{plg}/D_{qtz} ratios are systematically decreasing with high bulk strain intensities indicating common yielding of all mineral phases. The medium-grade orthogneiss plots show very low strain ratios of all mineral phases irrespective to the bulk strain, which indicate only weaker degree of strain partitioning.

Microstructural and quantitative textural analysis including grain size measurements, grain shape and grain boundaries were carried out to determine deformation mechanisms in the orthogneisses. The LCU orthogneiss shows fracturation and myrmekite reaction-driven disintegration of K-feldspars. Quartz forms lenses to ribbons with highly curved grain boundaries. Plagioclase shows tiny grain size (X0 μm) for all strain intensities. The UPU orthogneiss shows blebs of quartz composed of large (up to 5 mm) grains with straight boundaries. These inclusions are surrounded by monomineralic bands of K-feldspar and plagioclase. Feldspars show equigranular mosaic with abundant triple point junctions and straight grain boundaries. The interstitial plagioclase and quartz coating K-feldspar grains may indicate minor contribution of melting in high-energy structural sites. Grain-size statistics of quartz from the LCU show an increasing grain size and spread with increasing deformation, which also holds for the UCU samples. Feldspars show slight increase in grain size in samples from the LCU; the aspect ratio is almost constant for plagioclase. In the UCU samples the grain size rapidly decreases, whereas the aspect ratio remains stable and low. The crystal preferred orientation (CPO) was measured for quartz, plagioclase and K-feldspar in a weakly deformed sample from the para-autochtonous unit and in the highly strained sample from the LCU using the EBSD method. Strong CPO pattern of quartz is consistent with basal <a> and prismatic <a> glide systems while CPO of plagicolase is absent. Recrystallized K-feldspar shows strong CPO being consistent with activity of (010)<001> slip. The strongly deformed sample shows weaker CPO for quartz as well as weakening CPO for K-feldspar indicating persistent activity of (010)<001> glide system.

The competency paradox between feldspars and quartz in high-grade rocks is explained by contribution of melt enhanced grain boundary sliding (diffusion creep) in feldspars, which increases their ductility with respect to dislocation creep of strong quartz. In lower degrees of deformation, the K-feldspar is strong exhibiting brittle deformation coupled with dislocation creep, while quartz deforms entirely in dislocation creep field. The weakest plagioclase shows grain boundary sliding probably enhanced with important fluid influx. With increasing strain, the K-feldspar and quartz deformation is probably accompanied with a switch in active slip system, which is responsible for strengthening of quartz. This study shows the importance of detailed microstructral and deformation studies of polyphase rocks to evaluate more realistic relative strength-competency of rock forming minerals in the crust.

The Northern Part of the Izera-Karkonosze Block: Fragment of the Saxo-Thuringian Passive Margin

Andrzej ŻELAŹNIEWICZ and Izabella NOWAK

Instytut Nauk Geologicznych PAN, Podwale 75, 50-449 Wrocław, Poland

The northern part of the Izera-Karkonosze Block, composed of Neoproterozoic granodiorites, greywackes, mica schists and c. 500 Ma granites, belonged to the trailing edge of the Saxo-Thuringian terrane which resulted from the break-up of Gondwana. By the early Devonian (Nowak et al., in preparation), this passive edge underwent extension and rifting. A swarm of the WNW-trending subvertical basic dykes intruded continental crust presumably parallel to the rift axis. Their geochemical features