Conditions and processes during metamorphic and igneous petrogenesis

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Processes such as nucleation and crystal growth, chemical diffusion, crystal dissolution and deformation fundamentally impact on the mineral content, mineral chemistry and texture of a rock. Studies on the nature and rates of these processes in rocks (e.g. Carlson 2002), their interplay (e.g. Baxter and DePaolo 2004; Selverstone 2005) and their dependence on changes in pressure, temperature and chemical environment with time (e.g. Gaidies et al. 2008) are required to better understand metamorphic and igneous petrogenesis. Recent advances in the development of analytical and experimental techniques allow for the integration of microstructure analyses of rocks and minerals with chemical and isotopic investigations at unprecedented high resolution (Keller et al. 2008). Combined with novel theoretical and computational capabilities, the natural record preserved in geological materials can now be studied through more realistic simulations of mineral reactions in rocks accounting for fundamental thermodynamic, kinetic and mechanic principles (e.g. Schmid et al. 2009). Quantitative knowledge of the conditions and processes that control mineral formation in rocks is essential for a better understanding of the close relationship between the bulk properties of rocks and the way solid Earth responds to changes in external forces. It can be expected that this knowledge will help developing a successively more

realistic picture of the dynamics of our planet considering for instance the relevance of the extent of mineral reactions in rocks for catastrophic rock failure such as seismogenic slip (e.g. John et al. 2009).

This special issue originates from the session “Controls on metamorphic processes” held at the European Geosciences Union General Assembly 2008 in Vienna. It extends the original focus of this session on metamorphic petrogenesis to conditions and processes also fundamental for igneous rock formation and covers a broad spectrum of topics ranging from fluid-rock interactions on the outcrop scale to intracrystalline chemical diffusion and nucleation. Eight papers are included that address various themes relevant for a better understanding of metamorphic and igneous petrogenesis.

Habler et al. (2009) investigate the interplay of deformation, chemical equilibration and mineral reaction during Cretaceous metamorphism in polymetamorphic rocks from the Austroalpine Matsch Unit west of the Tauern Window in the European Eastern Alps. Based on detailed studies of mineral chemistry and rock microstructure, different mechanisms of interrelated deformation and chemical re-equilibration could be identified. Habler et al. conclude that understanding the mechanisms of the mutual interrelation between deformation and equilibration is required to deduce thermobarometrical constraints from deformed metamorphic rocks.

In order to derive estimates for the pressure and temperature conditions and timescales of polymetamorphism in the Wölz Complex (Eastern European Alps, Austria), Bestel et al. (2009) combine garnet isopleth thermobarometry with chemical diffusion modelling. The authors infer that during the Permian metamorphic event the rocks of the Wölz Complex were exposed to temperatures ranging from 570 to 610°C for about 10 to 20 Ma.

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This is opposed to about 0.2 Ma duration during the thermal maximum conditions that prevailed during the subsequent Eo-Alpine event in the Cretaceous.

Prenzel and Abart (2009) study polymetamorphic garnet-bearing metapelites from the Rappold Complex (Eastern European Alps, Austria). Garnet is found to form reaction rims at staurolite-quartz interfaces and individual grains along former contacts between staurolite and white mica. Based on the investigation of microstructures, Prenzel and Abart demonstrate that the mineral assemblage garnet + kyanite + biotite + paragonite was formed at amphibolite facies grade during Eo-Alpine metamorphism while staurolite and plagioclase broke down successively with increasing pressure.

Based on petrological and geochemical data and diffusion modelling Adamuszek et al. (2009) demonstrate that the composition of magmatic enclaves observed in the Karkonosze Granite (Czech Republic) was affected by two processes during granite — mafic melt interaction: (1) Assimilation of granitic melt during the injection of the lamprophyric melt and the subsequent flow of the forming enclaves in the gravity field and (2) diffusion-controlled redistribution of elements between both solidifying rock types due to late-stage magmatic fluids.

The contribution of Milke et al. (2009) focuses on results obtained from experiments on orthopyroxene formation at polished olivine-quartz interfaces. The experiments were conducted at 1.9 GPa and temperatures of 750 to 950°C using a piston-cylinder solid medium press. Despite the drying of the samples at 600°C before the experiments, the bulk diffusivity data derived from orthopyroxene growth rates are 4 to 7 orders of magnitude higher than expected for really dry experiments. This indicates effective hydrogen or water diffusion through the walls of the gold capsules that are commonly used in conventional experimental setups.

Luvizotto et al. (2009) investigate the prograde formation of rutile from ilmenite in medium-grade metasedimentary rocks from Erzgebirge (Germany). Based on systematic investigations of the Nb/Ti ratios in both phases, Luvizotto et al. suggest that rutile did not fully equilibrate with the remaining ilmenite in rocks that were exposed to metamorphic peak temperatures of less than 480°C, whereas rutile from the higher T rocks did. They apply the Nb/Ti ratio of the newly formed rutile as an indicator for closed- or open-system mineral reactions and confirm that higher temperatures favour larger-scale element transfer even of the so-called immobile elements such as Nb and Ti.

Abart et al. (2009) investigate the microstructure and chemical pattern of perthitic feldspar megacrysts from the Weinsberg granite (Moldanubian Zone, Austria). Numerical modelling of microstructure development suggests that the abundance, size and shape of the exsolved albite-rich

precipitates depend on the integrated bulk composition of the different growth zones of the megacrysts. Abart et al. argue for two different mechanisms that produced the observed microstructure. Whereas spinodal decomposition or nucleation at high nucleation rates is proposed for growth zones with intermediate composition, nucleation at low nucleation rates is suggested for orthoclase-rich growth zones.

The paper by Traskine et al. (2009) focuses on pressure solution creep of NaCl, CaCO₃, and NH₄NO₃ based on ball indentation and powder compaction experiments employing static and cyclic loading-unloading devices. Traskine et al. found that the transition from a static to a cyclic regime results in an increased creep rate, which lasts over the whole time of cyclic impact. In addition, it could be demonstrated that the creep rate slows down over longer-term tests at both static and cyclic conditions.

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