Microstructure evolution during metamorphic crystallization: Insight into transport and interface kinetics

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The thermodynamic analysis of phase equilibria in metamorphic rocks yields quantitative insight into P-T-X conditions of crystallization and provides important constraints for geodynamic models. Classical phase petrology does, however, not fully exploit the information that is engraved in the chemical zoning of minerals and in rock microstructure. The evolution of these phenomena is governed by the interplay of the underlying kinetic processes such as mass transport, interface motion and deformation. We present examples from nature and experiment to investigate into the kinetics of transport controlled mineral reactions and microstructure evolution. We combine mineral chemical and microstructural analysis at high spatial resolution with theoretical models based on irreversible thermodynamics.

We study reaction bands and corona structures which form at the interfaces of phases that can not coexist stably. With natural examples from eclogite facies and granulite facies metamorphism we address the pathways of mass transport and investigate into the role of grain boundary diffusion during reaction rim formation. With experimentally grown orthopyroxene reaction rims we address the effect of volume strain that is generally associated with a net transfer reaction. It is demonstrated that reaction induced deformation may influence rim growth rate. We also investigate the element partitioning at migrating reaction fronts. Chemical patterns indicate that equilibrium partitioning may be a rather localized phenomenon, and that the partitioning of minor components at moving interfaces may lead to secondary chemical zoning in either one of the reactant phases. Finally we present examples of phase separation in the alkali feldspar system. It is demonstrated that symmetry breaks and changes in Al-Si ordering during cooling may have a strong influence on the degree of coherency and on the mobility of the interfaces between the exsolved phases. It is shown that aqueous fluids may penetrate into perthithic alkali feldspar along incoherent phase boundaries, whereas coherent phase boundaries are largely impermeable to aqueous fluid.

Developing an ice core reconstruction of regional sea ice changes around Antarctica

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Sea ice is a critical but poorly understood component of Earth's climate system. A rapid decline in Arctic sea ice over recent decades has been documented using historical ship charts and satellite images. However, almost nothing is known about the behaviour of sea ice around Antarctica before routine satellite monitoring began, and proxy reconstructions of Antarctica's sea ice history are urgently needed to improve predictions of how Antarctic sea ice will respond to, and influence, future global climate change.

Ice cores from the Antarctic continent provide a potentially powerful archive for reconstructing sea ice changes. Our research uses an array of high-resolution ice core records from near-coastal sites around Antarctica, examining changes in the concentration of methanesulphonic acid (MSA) – a chemical species derived from plankton found at the sea ice margin. Using this network of MSA records we are able to develop an understanding of which ice core sites are most suited to provide reliable reconstructions of sea ice. This new network of ice core MSA records also suggests that there have been substantial regional differences in the variability and timing of sea ice decline around Antarctica during the 20th century. Comparison with sparse historical whaling records and sea ice charts supports these regional differences, suggesting that networks of ice core MSA records have the potential to improve our understanding of the characteristics and drivers of past sea ice changes around Antarctica.