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Introduction: linked processes of metamorphism and deformation

A. R. STALLARD[1] AND G. SOLAR[2]
[1]*Department of Geological Sciences, University of Canterbury, Private Bag 4800, Christchurch, New Zealand (aaron.stallard@canterbury.ac.nz)*
[2]*Department of Earth Sciences, SUNY College at Buffalo, 1300 Elmwood Avenue, Buffalo, New York, USA (solargs@buffalostate.edu)*

The interaction of deformation and metamorphism within the crust results in textures, structures and mineral growth that provide a record of tectonic activity as well as the progressive metamorphic and structural development of the crust. Analysis of these textures and structures is central to deciphering and evaluating the progressive nature of their development. Such rocks are commonly interpreted from the viewpoint of either structural or metamorphic processes; however, integration of these two perspectives has proved to be a powerful tool in enhancing our understanding of the structural development of metamorphic rocks at all scales. In recent decades, research into the linkages between metamorphism and deformation has increasingly involved the integration of textural, chemical and structural data.

The present volume arose from a topical session titled 'Understanding Coupled Metamorphic and Deformational Processes: Advances in Integrated Textural, Chemical and Microstructural Analysis' held at the 2003 annual meeting of the Geological Society of America, Seattle, USA. We were pleased that the session attracted 21 contributions from 48 geologists representing seven countries. The breadth of topics covered by the presentations, and the interest expressed by both participants and attendees encouraged us to assemble a set of thematic papers related to the topical session. The result is the present special issue of the *Journal of Metamorphic Geology*.

Whitmeyer & Wintsch document the linkages between stress, metamorphic reactions, grain shape-preferred orientation (SPO) and reactivation. They describe the reactivation of an amphibolite facies ultramylonite along discrete greenschist facies mylonitic shear bands. A random SPO within the ultramylonite created a texturally hardened rock that displaced strain into adjacent weaker foliated gneiss. Later replacement reactions within the ultramylonite were concentrated at areas of high stress and resulted in a chemical and mechanical softening of the rock via the development of a SPO of muscovite, chlorite and quartz. Reactivation of the ultramylonite was localized along discrete mylonitic shear bands at the sites of these reactions and accompanying SPO development.

The relationship between strain and SPO development is also explored by Stallard *et al.* who measured the 3D shape, size and orientation of quartz grains sampled along two transects of increasing metamorphic grade in the Otago Schist, New Zealand. Quartz SPO was initiated by dissolution–precipitation creep at sub-greenschist facies conditions, and was triggered by strain accompanying fold development. Detrital grains became blade-shaped, and were an important component of the metamorphic foliation. A second fold event, accompanied by crenulation cleavage development and resulting segregation of the rock mass, initiated a change in both the texture of the quartz SPO and deformation mechanisms. Previously discrete and aligned detrital quartz grains were replaced by aggregates and layers of dynamically recrystallized quartz grains of reduced aspect ratio and alignment. Pressure solution then affected the margins of quartz-rich layers rather than individual grains. The authors emphasize the contribution of quartz SPO to foliation development and the significance of fold events as a control on SPO formation and development. In a companion paper that analyses the 3D shape, size and orientation of white mica grains from the same samples, Stallard & Shelley describe the initiation and development of white mica SPO with increasing metamorphic grade. The character of white mica SPO is determined early in the deformation and metamorphic history. The onset of penetrative strain metamorphism is marked by the rapid elimination of poorly oriented large clastic micas in favour of numerous new smaller metamorphic grains of contrasting composition, higher aspect ratio and a strong SPO. The SPO results from the progressive competitive anisotropic growth of blade-shaped grains so that the fastest growth directions and blade lengths tend to parallel the extension direction during deformation. The competitive nature of mica growth is indicated by the progressive increase in size and resultant decrease in number of metamorphic mica with increasing grade, from *c*. 1000 relatively small mica grains per square millimetre of thin section at lower grades, to *c*. 100 relatively large grains per square millimetre in higher-grade samples.

Selverstone describes how changes in fluid composition correlate with changes in mechanical behaviour of graphitic schists during decompression. Interlayered graphitic and non-graphitic schists from the Tauern Window, Eastern Alps, record different mechanical behaviour during extensional exhumation. Graphitic schists contain brittle extensional structures oriented perpendicular to the stretching lineation, whereas non-graphitic schists have fewer and more randomly oriented microcracks and maintain strain compatibility via crystal plasticity. These observations are explained by the fact that carbonic pore fluids within the graphitic layers record $>60\%$ expansion during decompression compared with $<15\%$ expansion of H_2O-rich fluid in non-graphitic rocks over the same pressure interval. The greater pore fluid expansion in low-permeability graphitic horizons likely promoted tensile failure during unroofing. The presence or absence of graphite therefore influenced metamorphic fluid composition, which in turn profoundly affected the mechanical behaviour of the crust. Selverstone concludes that graphite may play an active role in embrittlement of the crust during decompression, and hence contribute to enhanced seismicity, particularly in areas undergoing extension.

Berg & Moecher investigated the extent to which oxygen isotope and major-element equilibria between porphyroblast and matrix minerals in regional metapelites are impacted by multiple periods of foliation formation. Upon initial analysis, the isotopic temperatures appear to be in excellent agreement with one another, and suggest that oxygen isotope equilibrium was attained between garnet and staurolite at *c*. 600 °C. However, the authors concluded that garnet and staurolite could not have simultaneously achieved oxygen isotope equilibrium with each other or with other minerals in the recrystallized matrix. This conclusion was based on the slow nature of oxygen diffusion rates in staurolite and garnet and the fact that matrix phases are able to exchange isotopes via recrystallization during each period of deformation. Instead, the Qz-Gt and Qz-St fractionations are apparent fractionations between porphyroblasts formed at different temperature and times in the prograde *P–T–D* path, and quartz that recrystallized and exchanged with micas and plagioclase during several phases of deformation.

We hope that the papers within this issue will highlight the linked nature of metamorphic and structural processes, and foster continued innovative research into the fundamentals of ductile deformation.