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Microstructural record vs chemical and geochronological preservation in muscovite: implications for P-T-t estimates in deformed metapelites

Laura Airaghi (1), Pierre Lanari (2), Clare J. Warren (3), Julia de Sigoyer (1), and Stéphane Guillot (1)

(1) ISterre, Université Grenoble Alpes, France , (2) Institute of Geological Sciences, University of Bern, CH-3012 Bern, Switzerland, (3) School of Environment, Earth and Ecosystem Sciences, The Open University, Milton Keynes, MK7 6AA, UK

Pressure-temperature-deformation (P-T-ε) paths for metamorphic rocks commonly relies on the link between successive metamorphic assemblages and the microstructures. However, with increasing P-T conditions, metamorphic minerals in an early microstructure can re-equilibrate by changing their chemical composition. The direct link between deformation phases and mineral compositions for thermobarometry purposes can therefore be distorted. This study focuses on a series of garnet-biotite metapelites from the Longmen Shan (Sichuan, China) that preserve muscovite of different chemistry in distinct microstructures. To quantify the degree of re-equilibration of muscovite, a microstructural study was coupled with high-resolution chemical mapping. Then, the chemical evolution of muscovite (Si^{4+} and X_{Mg}) was modeled using Gibbs free energy minimization along a P-T loop previously constrained by phase equilibria calculations, semi-empirical and empirical thermobarometry.

Our results show that the studied metapelites experienced a "typical" three stages metamorphic history: (1) heating and burial up to 11 kbar, 530°C, (2) minor decompression and heating up to 6 kbar, 580°C and (3) decompression and cooling down to 4-5 kbar, 380-450°C. However, muscovite has been partially or completely re-equilibrated during the three stages by idiomorphic replacement, although it is mainly observed in prograde microstructures preceding the pressure peak. The main factors controlling the degree of re-equilibration are the intensity of the deformation and the fluid availability during metamorphism. The P-T conditions of metamorphic assemblages thus reflect pulses of fluids release that enhanced mineral resorption and local replacement. The metamorphic peak (2) was dated by *in situ* $^{40}Ar/^{39}Ar$ on biotite porphyroblasts and by *in situ* (U-Pb)/Th laser ablation on allanite (REE-rich epidote) at 185$\pm$15 Ma. Muscovite grains preserved in prograde microstructures and partially re-equilibrated during stages (2) and (3) yield younger ages, at 150$\pm$10 Ma. These results, in apparent contradiction with the microstructural observations, suggest a key role of grains size and deformation and re-equilibration in the Ar recording. The micro-chemical behavior unrevealed in this study is probably relatively common in metapelites and questions the reliability of the P-T-t predictions based on relict phase chemistry, apparently preserved in microstructures that might have been affected by later re-equilibration.