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 rely 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\(_{\text{Mg}}\)) 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±15 Ma. Muscovite grains preserved in prograde microstructures and partially re-equilibrated during stages (2) and (3) yield younger ages, at 150±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.