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# Metamorphic reactions in deformed mafic rocks: timing, fluid percolation and equilibrium scales from undeformed gabbros to mylonites

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Within the Earth crust metamorphic reactions strongly participate to strain partitioning and localization. However, the timing of metamorphism relative to viscous deformation, the spatial scale of metamorphic processes and mineral re-equilibration remain elusive, with metamorphic reactions and associated fluid percolation generally considered as syn-kinematic. We investigate how, where and when (relative to viscous deformation) metamorphic reactions occurred in deformed gabbros of the Poroshiri Ophiolite of Hokkaido (Japan), in the core of a plate-boundary dextral shear zone. In these rocks, low and high strain areas preserve evidences of amphibolitization that occurred at 850-950°C (~5 kbar), triggered by fluid influx during fracturing (active in supra solidus conditions) and predating the viscous deformation. The abundance, composition heterogeneity of amphibole and the location of amphibole nucleation sites were regulated by water availability and by different reaction mechanisms as epitaxial growth or dissolution-reprecipitation observed at the nanoscale which controlled the magnitude and pathways of element supply (especially Fe and Mg). Pre-shearing metamorphism was accompanied by the local partial melting at grain boundaries and along crystallographic discontinuities of igneous clinopyroxene and resulted in grain size reduction of two orders of magnitude and formation of a patchwork of domains with different composition, where local chemical equilibria prevailed at the scale of 100-500 µm. Shearing occurred along the retrograde path, at 650-750°C and was coeval with amphibole and plagioclase recrystallization in high strain areas and in late fractures. Although fluid influx and amphibolitization reactions continued during shearing as attested by variations in major element content between high and low strain areas, mineral composition heterogeneities inherited from the pre-shearing metamorphic stage were largely preserved despite high strain and temperature, indicating in mylonites equilibrium scales shorter than 500 µm. Minor variations in amphibole modal abundance between inside and outside shear zones indicate that amphibolitization largely predated shearing and was controlled by fluid availability (through fracturing) rather than being strain-driven, with shearing mainly reworking the size and chemistry of amphibole grains. While throughout tectonic evolution, fluid infiltration primarily resulted from brittle fracturing active before and during viscous deformation,

areas of pre-shearing amphibolitization appeared as preferential loci for strain localization and mineral re-equilibration during shearing. Pre-shearing metamorphism influenced strain localization and mineral re-equilibration during shearing also by controlling (i) the grain size reduction, (ii) the degree of phase mixing, (iii) the distribution of hydrated phases (and therefore of stored fluid) and (iv) the strain partitioning among the inherited metastable mineralogical domains.