Argon closure system of phengites in high-pressure schist belts, Japan: Implication for exhumation process

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The high-pressure schists have been strongly deformed as observed in microstructural features that include a strong stretching mineral lineation and sheath folding. Wallis et al. (1992) demonstrated that the microstructures were formed during a post-metamorphic stage, suggesting that the ductile deformation took place during the exhumation and cooling of the high-pressure schist belts. Itaya and Fujino (1999) observed that phengite in the schists generally occurs as aggregates of fine-grained crystals and is also extremely fine-grained in domains close to rigid garnet, suggesting the size reduction of phengite by strain-induced or dynamic recrystallization. Strain-induced recrystallization promotes the chemical reaction of phengites during the retrograde stage as documented in many metamorphic sequences (Itaya & Fujino 1999; Miyashita & Itaya 2002; Takeshita et al. 2004; Gouzu et al. 2006). Recrystallization with significant re-arrangement of major elements such Al and Si in the phengite crystal should involve argon release from phengite as the trapped argon is not favored in the K site of phengite, and easily diffuses out from the crystal structure. In contrast, phengite inclusions in rigid garnet grains, which have higher Si values than the matrix phengites, does not release argon. This was documented by Gouzu et al. (2006) who showed that the phengite inclusions in garnet is significantly older than that in the matrix based on 40Ar/39Ar spot analyses. Thus, the ages obtained are related directly to the ductile deformation history of the matrix phengite during exhumation and cooling of the host rocks.

The mafic rocks such as the amphibolites are rigid in comparison with the associated pelitic schists and could be relatively resistant to strong deformation of the metamorphic pile. The phengites in the mafic rocks could be also protected from the deformation. In fact, they occur generally as coarse single crystals and are significantly older than those in pelitic schists. This means that they are likely to have suffered insignificant argon loss during the exhumation of the metamorphic pile.

Argon closure system of phengites in a whole metamorphic sequence, which has been deformed during the exhumation and the cooling of rocks, is controlled to a large extent by the onset of brittle deformation in the low-grade sequence. This is because the brittle deformation zone or the fault formation zone absorbs the strain of the whole sequence and the ductile deformation in the high-grade zone is restricted. The brittle deformation depends on a number of variables including lithology, pressure, strain rate and the presence or absence of fluids. Nuong et al. (2008) suggest that the onset of brittle deformation depends mainly on the strain rate of deformation during the exhumation of metamorphic pile. The significantly different strain rates result in the contrasting age-temperaure-structural relations for two metamorphic sequences of central Shikoku (west) and Kanto Mts. (east) areas in the Sanbagawa belt, and Ishigaki (west) and Nishiki (east) areas in the Suo belt: the western areas that have the inverted thermal structure has a positive correlation in age-temperature relationship and the eastern areas where the thermal structure for the higher-grade zone is in the lower part of the apparent stratigraphic succession, displays a negative correlation.