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Formation process of Al-rich calcium amphibole in quartz-bearing eclogites from The Sulu Belt, China

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Abstract

Aluminum-rich and Si-poor calcium amphibole [~3.9 Al atoms per formula unit (apfu) and ~5.5 Si apfu for 23 O] occur in the quartz-bearing eclogites from the Donghai area, Sulu ultrahigh-pressure metamorphic belt, eastern China. Most of the aluminous amphibole phases are retrograde products from the exhumation and hydration stage and are texturally divided into a mantle phase around a porphyroblastic garnet and a crack-filling (vein) phase of a garnet. Less aluminous amphibole occurs as symplectite phase with plagioclase after omphacite. The formation process of the aluminous amphibole in the quartz-bearing samples is discussed on the basis of the analytical data by EPMA, FIB-TEM, and EBSD.

The mantle amphibole occurs between garnet and symplectite or quartz. A set of plagioclase and aegirine-diopside/argirine-hedenbergite thin monomineralic bands forms at the boundary between the mantle amphibole and matrix quartz. However, these monomineralic bands do not occur at the mantle amphibole-symplectite boundary. These textural differences indicate that the recrystallization of the aluminous amphibole around garnet was controlled by significant local reactions, and the size of equilibrate domains was probably several tens of micrometers or less.

The mantle amphibole is composed of inner (garnet-side) and outer (matrix-side) zones. The inner zone is compositionally homogeneous, and its atomic Al/Si value is ~0.63–0.66 and similar to that of garnet. Atomic Ca/Si value in the inner zone is also almost uniform and is generally identical to that of garnet. The outer zone exhibits a monotonic decrease in the Al/Si and Ca/Si values outward, and its composition at the outermost margin is similar to that of the symplectitic amphibole. The crack-filling amphibole has a composition similar to the inner zone of the mantle amphibole. The CPO pattern of the crack-filling amphibole is different from that of the adjacent mantle amphibole, showing that the crack-filling amphibole is cut by the mantle amphibole. The textural relationship between the mantle and crack-filling amphibole phases and their compositional characteristics imply that: (1) the mantle type is a slightly later stage product than the crack-filling type, and (2) the boundary between the inner and outer zones of the mantle aluminous amphibole probably corresponds to the initial surface of the porphyroblastic garnet. The inner zone is considered to have grown inward by simple substitution of garnet, using the tetrahedral and octahedral cations of the garnet as the basic framework. On the other hand, most of the outer zone of the mantle-type amphibole grew outward in the matrix from the initial surface of the garnet porphyroblast. The mantle amphibole shows a CPO similar to that of amphibole in the adjacent symplectite domain, suggesting that these two types of amphibole formed almost simultaneously, sharing crystallographic orientation with each other.

The formation of crack-filling aluminous amphibole was probably promoted by the hydraulic microfracturing process at an early stage of exhumation and hydration. The mantle and symplectitic amphibole phases formation was promoted by the subsequent infiltration of metamorphic fluid. The aluminous amphibole in the SiO_2 phase-bearing eclogites probably recrystallized with the formation of a localized SiO_2-undersaturated reaction domain because of rapid exhumation and subsequent rapid cooling of the Sulu UHP metamorphic belt.

Keywords: Aluminous amphibole, EPMA, FIB-TEM, EBSD, eclogite, Sulu UHP metamorphic belt