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Exhumation and strain rates in the Sambagawa metamorphic rocks inferred from amphibole zoning and quartz microstructures

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The Sambagawa metamorphic rocks suffered not only a large amount of plastic deformation, but a significant retrograde metamorphism. In order to clarify the P-T path and physical conditions for deformation during the exhumation, we have been working on the analyses of (1) chemical zoning in metamorphic amphibole, and (2) deformation microstructures in quartz. Since the amphibole mostly grew at retrograde conditions during the exhumation, it is a good tool to estimate the exhumation P-T path. Furthermore, the chemical zoning in fine-grained amphibole, which grew during the prograde stage and included in the core of plagioclase porphyroblast, can provide us with the prograde P-T path. On the other hand, based on c-axis fabric, and size and shape of recrystallized quartz grains, it is possible to infer the physical conditions (temperature, strain rate and differential stress) for deformation.

The present study has revealed that the whole P-T path from subduction to exhumation, which can be inferred from chemical zoning in both inclusion and matrix amphibole, can be divided into two types: a clockwise and hairpin types, which dominate in the Asemi (northern part) and Saruta River (southern part) areas, respectively. Therefore, it could be inferred that rocks in the Asemi River area was more rapidly elevated and decompressed than those in the Saruta River area. Furthermore, it has been found that the retrograde zoning in amphibole can be divided into three types, sodic, sodic-calcic and calcic series, the formation of which could have been also influenced by the exhumation rate.

Type I crossed, small and cleft girdle quartz c-axis fabrics with a small half-opening angle of ca. 30o dominate in quartz schist throughout the Sambagawa belt, central Shikoku. These c-axis fabrics appeared to have been formed by dominant basal[a] and rhomb[a] slip under low temperature conditions (300-450 oC). On the other hand, only in some part of the oligoclase-biotite and albite-biotite zones in the Asemi River area, type II crossed, small and cleft girdle c-axis fabrics with a somewhat larger half-opening angle occur. These c-axis fabrics were perhaps formed by dominant basal[a] and prism[a] slip under intermediate temperature conditions (450-550 oC). The intermediate-type c-axis fabrics could have been frozen, probably because of a rapid cooling, consistent with the rapid exhumation rate inferred from the chemical zoning in amphibole from the Asemi River area. Recrystallized quartz grain size in quartz schist increases from 30 to 180 microns with increasing peak-metamorphic grade. The fact means that the formation temperature for microstructure increases with the increasing peak-metamorphic grade, consistent with the above conclusion based on c-axis fabric patterns that the higher grade rocks were exhumed and cooled rapidly. While the recrystallized grain size is not much different between samples from the Asemi and Saruta River areas, its aspect ratio (R) in the chlorite and garnet zones is higher in the Asemi (S-type) than in Saruta (P-type) River area. Considering the experimental results by Masuda and Fujimura (1981), the fact probably indicates that rocks in the Asemi River area suffered a higher strain-rate deformation than those in the Saruta River area.

In order to explain the differences in P-T path and strain rate in the Asemi and Saruta River areas, we propose a model where rocks in the Asemi River area (a lower plate) structurally underlie those in the Saruta River area (a upper plate), bounded by a normal fault. In this model, rocks of the lower plate are exhumed more rapidly than those of the upper plate due to a normal displacement along the fault, which could explain the observed difference in P-T path between the two areas. Furthermore, the model may explain the difference in strain rate inferred from quartz microstructures between the two areas, because the lower plate tended to support more stress than the upper plate.