Carbonic fluids of the retrograde metamorphism in the Ryoke metamorphic belt

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At the Takabatake outcrop in the Yanai district, Yamaguchi prefecture, quartz veins occur in pelitic and siliceous rocks of the biotite zone of the Ryoke metamorphic belt. Yamamoto et al. (2004) reported that the veins in pelitic rocks are orientated parallel to the schistosity and form boudinage due to the ductile flow of the host rock, while those in siliceous rocks are oblique to the schistosity and have not undergone ductile deformation. They also concluded that the veins were formed under flow deformation conditions during retrograde metamorphism, probably at temperatures above 300C. Fluid and solid inclusions in the veins have been investigated to clarify characteristics of the vein-forming fluids.

According to Hirotaka and Hoshino (2007), liquid and vapor phases of the inclusions in the veins are of the H2O-CO2 (-CH4) system with low salinities ranging from 0 to 4 NaCl eq.wt%. Daughter minerals and minerals that have been accidentally trapped in the fluid inclusions are carbonaceous matter (CM), muscovite and native sulfur. They characterized the CM as: Type 1 CM with a small grain size in the fluid inclusions, Type 2 CM having a large proportion of the volume and Type 3 solid CM without any fluid. The latter two types are probably accidentally trapped from CM precipitated from the vein-forming fluids. They also estimated the organization temperature of the Types 1, 2 and 3 CM as 641-592, 628-534 and 570-530C, respectively.

On the other hand, the CM in the host pelitic rocks showed their organization temperatures as 637-565C. The temperatures are higher than those estimated from metamorphic mineral assemblages by Ikeda (2004) (450-453C). The R2 ratios of the CM in the quartz veins and the host pelitic rocks of the biotite zone are similar to those of the cordierite zone in the Yasaka contact aureole around the Cretaceous Hiroshima granite, 10 km north of the Takabatake outcrop. Accordingly, it can be thought that the rocks in the biotite zone were affected by the same contact metamorphism probably by thermal fluids at the retrograde stages of the Ryoke metamorphism, although its effect was not recorded in the metamorphic mineral assemblages. Therefore, it can be said that the degree of organization of the CM may reveal much detailed thermal histories than those recorded in the metamorphic minerals.

The quartz veins in the pelitic rocks show two distinct phases of quartz crystallization revealed by contrasting CL light intensity, recording a two-stage history of vein formation. The first generation of quartz (Qt-1) is characterized by bright luminescence, and observable at core of quartz grains. The second generation (Qt-2) is volumetrically subordinate but presents in all quartz grains and shows gray and dark luminescence. The Qt-2 occurs in the Qt-1 grains as healed microfractures and grain boundaries resulted from healing and partial dissolution of Qt-1. The CM inclusions are particularly abundant in Qt-2 showing a 'turbid' appearance in transmission light, owing to the abundance of minute fluid and CM inclusions. The quartz veins in the siliceous rocks in the zone also consist of the CL-bright quartz grains and CL-gray and dark quartz gains, rims and healed microfractures. The CL imaging revealed that the almost fluid inclusions are secondary in origin. Fluid inclusions in trails parallel to the boundary between the host siliceous rocks and the veins are also of the H2O-CO2 (-CH4) system. Hence, it can be concluded that the H2O-CO2 (-CH4) fluids may have continued to flow after vein-formation at the retrograde metamorphism.