

Skarnization at the Sekine area, Yonezawa City, Yamagata Prefecture, northeast Japan: estimation of the formative environment

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The Sekine area, Yonezawa City, is located at the eastern side of the Tanagura Tectonic Line and belongs to the Abukuma Belt. The area is underlain by hornblende-biotite granodiorite of Cretaceous age, and amphibolite, marble and biotite schist called Sekine metamorphic rocks, which are covered by pyroclastic and sedimentary rocks of Cenozoic age. Typical Skarn develops at the contact between the granodiorite and the marble. In the present study, hornblende geobarometer, amphibole-plagioclase geothermometer, and microthermometry are applied to understand the formative environment of the skarn.

The chemical composition of amphiboles in the granodiorite and amphibolite are classified into ferro-hornblende to ferro-actinolitic hornblende, and magnesio-hornblende, respectively. Si contents of amphiboles in the granodiorite are almost as same as those in the amphibolite, whereas Al contents of amphiboles in the granodiorite are slightly higher than those in the amphibolite. Based on the hornblende geobarometer by Schmidts (1992), the formative pressures of granodiorite and amphibolites are estimated to be 3.2(error of plus or minus 0.6) kbar and 2.8 (error of plus or minus 0.6) kbar, respectively.

On the basis of the amphibole-plagioclase geothermometer by Blundy and Holland (1990), formative temperatures of granodiorite and amphibolites are estimated to be 699.7~715 degrees (av. 714.5 degrees) and 695.3~713.9 degrees (av. 711.4 degrees), respectively.

Homogenization temperatures of primary inclusions in quartz from granodiorite are in the range of 315 and 345 degrees (av. 337 degrees), and the salinities are ranging between 7.4 and 8.6 wt.% (av. 7.7 wt.%). Homogenization temperatures of primary inclusions in calcite from skarn are in the range of 315 and 348

degrees (av. 335 degrees), and the salinities are between 1.2 and 1.7 wt.% (av. 1.3 wt.%). Homogenization temperatures of primary inclusions in calcite from marble have a wider range of 188 and 307 degrees (av. 335 degrees), and the salinities are between 6.8 and 9.5 wt.% (av. 7.4 wt.%). Considering that the inclusions of calcite in marble contain gaseous phases such as CO₂ and CH₄, the salinities of primary inclusions in calcite from the marble are estimated to be slightly higher than those from the skarn. By the estimation using an isoclinic line by the homogenation temperature and the salinity of the inclusions by substitution of the pressure obtained by hornblende geobarometer, the temperature of this skarn is estimated to be 700 degrees, which agrees closely with the temperature by the amphibole-plagioclase geothermometer being shown previously.

Lower salinity of fluid inclusions from granodiorite, skarn and marble suggest that skarn-forming fluid were undersaturated with water. The estimated environment of formation (higher temperature and pressure, and unsaturation with water) indicates that the skarn had been formed at the lower position of the intruded granodiorite body. Extremely lower enrichment of heavy metals might be due to such environment of formation.