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Heat transportation recorded in the southern part of the Hidaka metamorphic belt

SAKATA, Ryugen[1*] ; OZAWA, Kazuhito[1]

[1]School of Science, The University of Tokyo

The earth's continental crust has granitic upper crust and gabbroic lower crust with andesitic average composition, which was developed by various magmatic processes driven by thermal and material transportation through the sub-continental crust-mantle boundary. There are three ways of heat transportation from the mantle to the crust with respective time and spatial scales: heat conduction, solid-state flow of the mantle and the crust, and magmatism. This study aims to evaluate the relative importance of these elemental mechanisms in an exhumed ancient arc crustal section, Hidaka metamorphic belt, Hokkaido, Japan.

Seismic wave tomography has revealed that the lithospheric mantle shows continuity to the shallow crustal level near the Hidaka Main Thrust, where the Horoman peridotite complex is exposed, suggesting shallow uplift of the upper mantle (Kita et al., 2012). The Horoman peridotite complex is shown to underwent isothermal ascent with local heating up to $<$1GPa followed by rapid cooling (Ozawa, 2004), which could have heated the lower crust. Previous studies pointed out that basaltic magma frozen as gabbroic bodies caused crustal partial melting and melt transportation on the basis of geological and geochemical data (Osanai et al., 1991; Owada et al., 2003; Tagiri et al., 1988; Shimura et al, 2006). However, the role of mantle-derived heat and its transportation mechanism are still unclear.

Field survey was conducted along the Nikanbetsu river in the southern end of the Hidaka metamorphic belt. In the study area, a small peridotite body called Nikanbetsu mass is exposed on the west and a large tonalite body on the east. Metamorphic rocks are distributed in between them. The dominant lithology is banded garnet biotite gneiss intercalating $<$100m thick zone of mafic metamorphic rocks, which consists of amphibolite and mafic granulite with many leucocratic veins and layers. The banded garnet biotite gneiss shows remarkable foliation except for the one located near the Nikanbetsu mass.

We applied biotite-garnet Mg-Fe exchange thermometer (Ferry and Spear, 1978) for average chemical compositions of biotite and garnet in the banded garnet biotite gneiss and leucocratic veins including garnet and biotite in the zone of mafic metamorphic rocks. The results show a temperature decrease by ~100 ℃ within ~1km from the east of the peridotite mass to the west of the tonalite body with an exceptionally high value of 750 ℃ around the mafic metamorphic rocks. An application of biotite-garnet thermometer to the core and the rim of the largest garnet and the average value of biotite gives $>$900 and ~750 ℃, respectively. The garnet zoning, occurrence of euhedral plagioclase with normal Na-Ca growth zoning, and weak foliation suggests partial melting of the rock followed by rapid cooling. We also applied two-pyroxene thermometer (Lindslay, 1983) for orthopyroxene coexisting with clinopyroxene in mafic metamorphic rocks with leucocratic veins. The calculated temperature ranges 1000~700 ℃, which is due to a decrease in Wo content from the core to the rim suggesting rapid cooling.

Veins with various structure, morphology, and chemical composition suggest diverse processes during melt transportation, such as brittle failure of the host rock, permeable leakage to and reaction with the host rock, and differentiation and crystallization in the veins. Less differentiated veins may have records of a melt directly migrated from the deep crust, whereas differentiated veins may have records of partial melting of pelitic gneiss.

We detected a thermal gradient of ~100 ℃/km from the Nikanbetsu mass, suggesting the mass acted as a heat source to affect the adjacent metamorphic rocks through heat conduction. We also detected a thermal gradient of $\gg$100 ℃/km around the zone of mafic metamorphic rocks generated by magma transportation overlapping the much gentler thermal gradient.

Keywords: Hidaka metamorphic belt, pelitic gneiss, peridotite, heat source, partial melting