Generation condition of primary magmas in the Hidaka metamorphic belt constrained by the Nikanbetsu gabbro complex

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The net growth of continental crust with chemical stratification and andesitic mean chemical composition started with addition of basaltic magmas generated in the mantle in arc environment (Arculus, 1981; Taylor & Mclennan, 1985; Rudnick, 1995; Hawkesworth & Kemp, 2006). The purpose of this study is to (1) clarify conditions of source regions of primary magmas and (2) examine role of the magmas played in the evolution of arc crust by scrutinizing the ancient deep arc crust, where key processes are expected to take place. We have chosen the Hidaka metamorphic belt, which was an uplifted arc by arc-arc collision accompanied by a high-temperature medium-pressure type metamorphism (Komatsu et al., 1986). The metamorphic belt represents a cross section of the arc crust exposed continuously from the upper crust to the upper mantle through the lower crust. We focus on gabbro complexes, which were slowly cooled basaltic magma bodies and could have preserved mantle derived magmas undergone limited fractional crystallization and crustal assimilation. We studied the Nikanbetsu gabbro complex, which occurs between two of the largest mantle peridotite bodies, Horoman and Nikanbetsu peridotite complexes.

The Nikanbetsu gabbro complex consists of various lithologies: troctolite-olivine gabbro (TROG), gabbronorite (GBNO), and quartz diorite-tonalite (DITO) in the order of increasing extent of fractionation and/or assimilation, which is indicated by the whole rock composition as well as Ca / (Ca + Na + K) of plagioclase and Mg / (Mg + Fe) of pyroxenes. They show a systematic distribution in the complex; TROGs are distributed in the peripheral part, DITOs in the central part, and GBNOs in between.

Coarse-grained intrusive rocks experience long crystallization history, during which many open-system processes could have modified the whole-rock chemical composition. Taking this into account, we chose fine-grained rocks reflecting the melt compositions for each lithology. Whole-rock chemical analyses of such fine-grained rocks with XRF show that TROGs belong to the tholeiite series and DITOs to the calc-alkaline series. This contrast is also evident in rare earth element (REE) patterns determined with ICP-MS; TROGs have LREE-depleted patterns, whereas DITOs have LREE-enriched patterns. We also examined whole-rock Sr and Nd isotopic ratios with multicollector-ICP-MS, which show that TROGs have lower $^{87}Sr/^{86}Sr$ and higher $^{143}Nd/^{144}Nd$ ratios, within the MORB array, than DITOs and GBNOs in between. The data form a linear trend extending from depleted MORB value to a slightly more depleted value than the BSE in the $^{87}Sr/^{86}Sr$ - $^{143}Nd/^{144}Nd$ plot. The geochemical data and field relationship suggest that the parent magma of TROGs formed by decompressional melting of the MORB source mantle and its emplacement into the Hidaka crust triggered formation of GBNOs and DITOs involving assimilation of ancient crustal materials.

The least differentiated fine-grained gabbro (0.5mm) with whole rock MgO content as high as 11wt% was found in the TROG group. The chemical composition is similar to that of basaltic dike in the Pankenushi complex (Maeda and Kagami, 1994). The rock has modal composition of plagioclase=60, olivine=12, clinopyroxene=24, orthopyroxene=1.8, and amphibole=1.8vol%. The whole rock water content is estimated to be 1.1wt%. Assuming that the whole rock composition represents melt composition, we calculate the chemical composition of primary magma in equilibrium with mantle peridotite by adding olivine in equilibrium with the melt until the Ni content in melt is consistent with the mantle olivine array of Takahashi (1986). The estimated primary melt composition contains 17wt% MgO. We calculate pressure and temperature conditions of the magma generation based on Sakuyama et al. (2009; 2014). Formation processes of the Hidaka arc crust are discussed on the basis of our field observation, geochemical data, and generation conditions of primary magma.