Ordovician mantle dynamics in NE-Japan constraints from layered structures of Cumulate Member in the Hayachine-Miyamori Ophiolite

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It is important to know the thermal history of the mantle in order to understand the evolution of the earth. Ophiolite pulses, in which a large number of ophiolites formed in a confined period, are thought to reflect superplumes [1]. However, the relationship between the Ordovician ophiolite pulses and the proposed plume model are debatable because of the predominance of arc ophiolite [2] and scarcity of LIPS for the Ordovician pulse [3]. In addition, [4] show that the Ordovician upper mantle at ~500Ma had a thermal state similar to the current upper mantle beneath mid-ocean ridges, and argued that the Ordovician ophiolite pulse is not attributable to high temperature of the upper mantle on the basis of estimation of the mantle potential temperature. If this is globally the case in the Ordovician time, we should examine the origin of Ordovician pulse under constraints of thermally quiet upper mantle.

The Hayachine-Miyamori Ophiolite, northern Japan, is one of the typical Ordovician ophiolite which has a hydrous upper mantle formed in arc environment. The ultramafic member was built up by three main magmatic stages, which are recorded in the three rock units in the ophiolite. They are, in the order of formation ages, Tectonite Member, which has penetrative plastic deformation texture, Cumulate Member, which has cumulus texture without evidence for solid-state deformation, and ultramafic dikes, which intruded into Cumulate Member [5]. This sequence of magmatism is explained by extensive partial melting under fluid influx in fore-arc followed by formation of cumulates from a melt generated by decompressional melting of the MORB-source-like upper mantle [5], and further followed by formation of dikes of an ultramafic magma formed by decompressional melting of the MORB source mantle at the depth as deep as ~170km [4]. The most plausible tectonic model for the sequence of magmatism in the Ordovician time in NE Japan is extensive hydrous melting in the wedge mantle, which was followed by trench retreat ending up with slab breakoff and upwelling of sub-slab mantle [5]. This model must be quantified for better understanding the catastrophic processes of slab breakoff from its beginning to the end, which could be relevant to the Ordovician ophiolite pulse. In order to obtain higher time-resolution of the events, we have established stratigraphy in Cumulate Member for acquisition of mineralogical and geochemical data in correct time sequence.

Our recent field study showed the presence of a large-scale layered structures characterized by the alternation of wehrlite and dunite in the Cumulate Member of the Miyamori complex. The individual layer has a thickness from several meters to ~1 kilometer and strikes N~50°W being consistent with the overall trend of the tectonite-cumulate boundary with strike of N~45°W. The structure and the occurrence of tectonite xenoliths exclusively along the boundary with Tectonite Member suggest that Cumulate Member formed by gravitational crystal settling with ~NE-SW gravity orientation. In order to specify the gravity vector, we examined mineralogical variations in a wehrlite-dunite layering over 15cm in total thickness. The Mg#, NiO wt% of olivine and Cr# of spinel decrease gradually from 0.88 to 0.85, from 0.25 to 0.21, and from 0.52 to 0.38, respectively from NE to SW. This direction of differentiation from NE to SW suggests that formation of Cumulate Member took place from E to W. We examined if there is a change of REE patterns of clinopyroxene at the core, which escaped from modification by the contact metamorphism of Cretaceous granodiorite intrusion, to evaluate the temporal change of the generation depth of the responsible parent magmas by garnet signature in the REE patterns as depth proxy.

[1] Ishiwatari, 1994 [2] Dilek & Furnes, 2011 [3] Ernst & Buchan, 2003 [4] Kimura et al., 2017, JpGU abstract [5] Ozawa et al., 2015

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