

Two stages of orthopyroxenite formation in the slab-mantle wedge interface

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The slab-mantle wedge interface is a site of intensive chemical-mechanical interactions between mantle and crustal rocks in the presence of a slab-derived agent (fluid/melt). Mantle rocks that suffered from Si-metasomatism probably play important roles in subduction interface processes such as mechanical coupling and recycling of volatile and incompatible elements, although the detailed petrological structure of the subduction interface and its spatial-temporal evolution are not well-understood.

We focus on the two important processes of orthopyroxenite formation along the slab-wedge mantle interface. One is metasomatic replacement of peridotite via the reaction $Ol + SiO_2$ (slab partial melt or solute-rich fluid) = Opx (R1). This process can occur at high-T conditions such as seen at forearc depths of infant subduction zones or subarc depths of matured subduction zones. The other is dehydration of Si-enriched serpentinite via the reaction $Tlc + Atg = Opx + H_2O$ (R2). This reaction takes place at low-T eclogite facies conditions and may be responsible for the maximum depth of decoupled slab-forearc mantle interface.

Natural records of these reactions have been discovered in the Western Iratsu body of the Sanbagawa belt, which consists of metabasaltic and minor ultramafic domains. This mafic-ultramafic complex represents an important natural laboratory to study slab-mantle interactions in an evolving subduction zone environment. Dunite is the major rock type of the ultramafic domain and grades into Opx-rich rocks (orthopyroxenite with a harzburgitic zone at the contact with dunite) at the mafic-ultramafic boundary. In addition, Opx-rich veins crosscut the whole sequence.

The earlier orthopyroxenite is mainly composed of coarse-grained orthopyroxene (Opx1: up to 1.3 wt% Al_2O_3) that include rounded olivine crystals and texturally primary multiphase solid inclusions (MSI). Olivine enclosed in Opx1 in the orthopyroxenite is enriched in Ni (up to 1.1 wt% NiO, Fo88-89) with respect to this mineral in adjacent dunite (up to 0.35 wt% NiO, Fo88-89), suggesting the progress of R1. Cores of Cr-spinel in the Opx1-bearing rocks and dunite show identical compositions ($Cr\#=0.83-0.87$, $Mg\#=0.20-0.29$, $TiO_2 < 0.4$ wt%) that are indicative of a highly depleted forearc mantle origin. These observations, in conjunction with previously constrained P-T-t history of the body, suggest that the Opx1-bearing rocks were formed by reactions between a slab-derived melt and the dunitic mantle wedge during the earliest stage of the subduction zone development. MSI in Opx1 probably represent remnants of residual melt/fluid after the progress of R1. LA-ICPMS analyses of MSI and the host Opx1 reveal that the residual melt/fluid (and also metasomatic agent) is rich in LILE, U, Th and LREE and only minor fraction of them resides in Opx1. Therefore, the metasomatic formation of orthopyroxenite permits transportation of the reactive slab-derived agent into the mantle wedge and recycling of the slab-derived incompatible elements.

The later orthopyroxene-rich vein consists of euhedral prismatic Al-poor orthopyroxene (Opx2: $Al_2O_3 < 0.04$ wt%) in association with antigorite, chlorite and tremolite. The mineral assemblage and the composition and morphology of Opx2 suggest Opx2-bearing veins were formed via R2 in the eclogite facies conditions. Before the dehydration veining, dunite and/or Opx1-bearing rocks must have suffered from hydration to form antigorite and talc by influx of H_2O -rich fluid. Opx2 is significantly lower in HFSE (Nb, Ta, Zr, Hf, Ti) and higher in fluid mobile elements (Li, B, Cs and Rb) than Opx1, supporting this interpretation.

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