Crystal mush reconstruction of a fully recrystallized metagabbro suite at Fuko Pass, Oeyama Ultramafic Body, SW Japan

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Mafic-ultramafic cumulate rocks that formed in magmatic crystal mush have a great potential to understand the process of fractional crystallization of minerals from magma and subsequent magmatic differentiation. However, petrological and geochemical studies of the cumulate rocks are scarce compared to those of "melt-frozen" rocks. In this study, we focus on a metamorphosed, "highly fractionated troctolitic to anorthositic cumulate" suite (Fuko Pass Metacumulates [FPM]: Tsujimori 1999) that occurs in the Oeyama ultramafic body of the Early Paleozoic Oeyama Belt, SW Japan. The FPM has been interpreted as a mafic-ultramafic cumulate member of an ophiolitic succession (Kurokawa 1985). Microtextural relationships and mineral chemistry define three metamorphic stages: relict granulite facies metamorphism; high-pressure epidote–amphibolite facies metamorphism; and retrogression. Relict Al-rich diopside (up to 8.5 wt% Al_2O_3) and pseudomorphs after spinel and plagioclase suggest medium-P granulite facies conditions (Tsujimori & Ishiwatari 2002). An unusually low-variance assemblage (Hbl + Czo + Ky ±St + Pg + Rt ±Ab ±Crn) implies high-pressure metamorphism; a retrograde margarite-bearing assemblage after kyanite indicates a greenschist facies overprint during decompression (Tsujimori & Liou 2004). Although FPM completely lacks relict magmatic minerals, a systematic bulk-rock geochemical study constrains magmatic natures and processes prior to metamorphic recrystallization.

We selected 85 samples from ˜250 kg metacumulate rocks randomly collected from an outcrop (˜15 ×2 m) at Fuko Pass. The samples were grouped into two types: leucocratic and melanocratic suites (LS and MS). Bulk-rock composition (SiO_2, TiO_2, Al_2O_3, $Fe_2O_3^T$, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5, Sc, V, Cr, Co, Ni, Cu, Zn, Ga, Rb, Sr, Y, Zr, Nb, Ba, Pb and Th) of 35 LS samples and 50 MS samples were analyzed using an XRF. Overall, LS samples are characterized by lower SiO_2 (39–41 wt%) with higher LOI values. In contrast, MS samples are characterized by higher MgO (13–19 wt%) and lower Al_2O_3 (5–13 wt%). Although some trace elements are highly modified during metamorphic recrystallization, proportions of normative minerals for individual samples suggest that the protoliths of LS and MS samples are troctolitic-anorthositic and wehrlitic-clinopyroxenitic cumulates, respectively. Assuming that compositional variations and trends of the samples reflected mixing among the parental melt and accumulated crystals, we estimated plausible chemical composition of the parental melt that coexisted with the accumulated crystals in magmatic crystal mush. The inferred parental melt has Fe-rich basaltic composition that allows a gravitational floatation of Ca-plagioclase at low pressure; the calculated melt density at 0.3 GPa and 1150°C reaches up to 2.75 g/cm^3. Considering their petrological evidence together with the geological context, the protolith of FPM would have formed beneath a slow spreading ridge where slow cooling and crystallization of Ca-rich plagioclase can occur. The Fe-rich parental melt might have formed by cotectic fractionation of plagioclase + clinopyroxene.

Keywords: metacumulate, protolith, anorthosite, crystal mush, Oeyama Ophiolite