Carbon flux and alkaline volcanism: Evidence from carbonatite-like carbonate minerals in trachytes, Ulleung Island, South Korea

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ABSTRACT
Carbon flux metasomatism in the subduction environment is an important process, but it remains poorly understood. The paucity of exposed lower crust and upper mantle rocks in continental arcs renders xenoliths a major target for studying the slab-derived carbon cycle. This study of the carbonate phases in volcanic rocks from three drill cores in Ulleung Island, South Korea, sheds light on the interaction of carbon flux in the upper mantle and lower crust in a back-arc setting. The volcanic rocks from Ulleung Island range in composition from trachybasalt to trachyte and contain abundant euhedral pseudomorphic carbonate grains, ulvöspinel-hosted and biotite-hosted carbonate-silicate melt inclusions, and irregular carbonate globules. Integrated petrographic and geochemical studies of a variety of phenocrysts, carbonate phases, and carbonate-silicate inclusions in biotite and ulvöspinel indicate that recharging of carbon flux affected magma evolution. Carbon and oxygen isotopes of the pseudomorphic carbonate grains overlap with mantle values, indicating a carbonatite-like origin of the carbonate phases. The MgO,FeO,CaO-rich silicates in ulvöspinel-hosted silicate inclusions and pseudomorphic carbonate grains likely represent a primary melt, which formed from the partial melting of carbonated eclogite of the subducted slab within the mantle wedge beneath Ulleung Island. A petrogenetic model is proposed to illustrate that the crystal mush in the magma chamber was intruded by carbonate-rich liquids and caused alteration of cumulate crystals to generate the euhedral pseudomorphic carbonate grains. The extrusive magma captured those pseudomorphic grains and erupted to form the trachybasalt-trachyte units. The observed carbonate phases and their geochemical characteristics indicate that carbon flux metasomatism played a fundamental role in this back-arc magmatism.

Keywords: Euhedral pseudomorphic carbonate grains, carbonate-silicate melt inclusion, carbon flux, trachytic magma, Ulleung Island

INTRODUCTION
Carbonate metasomatism is common in subduction zones (e.g., Yaxley et al. 1991; Daguupta and Hirschmann 2010; Johnston et al. 2011; Mason et al. 2017). The studies of the geochemical character of back-arc volcanism increased the understanding of the origin and evolution of supercritical fluids in subduction zones (Hack et al. 2007; Frezzotti and Ferrando 2015; Zhang et al. 2017). As a part of the variate components, CO2 emissions from volcanoes are an important part of the global carbon cycle (Burton et al. 2013; Kelemen and Manning 2015; Crémon et al. 2017). Carbon flux is an important agent in mantle metasomatism that contributes to mantle geochemical heterogeneity (Tilton and Kwon 1990; Daguupta et al. 2009; Whitley et al. 2019). Even though some subducted carbonates break down in the subduction zone and are released through arc volcanism, most of the subducted carbon can be transported into the deeper mantle (e.g., Bebout 1996; Jarrard 2003; Frezzotti et al. 2011; Whitley et al. 2019). The predicted global slab-derived carbon flux escaping from the subducted crust in the subarc region records only a portion of the carbon cycle (Kerrick and Connolly 2001; Jarrard 2003; Gorman et al. 2006; Bebout and Penniston-Dorland 2016; Whitley et al. 2019) and a large amount of carbon should be preserved in the mantle and crust due to metasomatism (Yaxley et al. 1991; Bebout 1996, 2007; Marty and Tolstikhin 1998).

Carbonatite is important for studying the long-term, deep carbon cycle within the Earth (Daguupta and Hirschmann 2010; Frezzotti et al. 2011; Hermann et al. 2013). Based on current studies, the influence of carbon flux on the formation of alkaline silicate rocks is highly speculative and the relationship between them has been controversial (Kogarko et al. 2001; Laporte et al. 2014; Zhang et al. 2017; Loges et al. 2019). Some alkaline silicate melts and their fractionation series can be closely linked to carbonate metasomatism (Yaxley et al. 1991; Kogarko et...