Fluorine and chlorine contents in Quaternary volcanic rocks from the Southern Volcanic Zone of Chile

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To investigate the along-arc compositional variation of halogens (fluorine and chlorine) in arc volcanic rocks corresponding to the age and thermal structures of the subducting slab, we analyzed halogen contents in representative lavas obtained from 10 volcanoes along the Quaternary volcanic front of Southern Volcanic Zone (SVZ) of the Andean arc in Chile. The contents of major and trace elements except for halogens in the samples used in this work were reported by Shinjoe et al. (2013), which are used for discussion in this study.
The SVZ is bordered by the Juan Fernández Ridge of the Nazca Plate to the north, and by the Chile Triple Junction (CTJ) between the Nazca and Atlantic Plates to the south. The SVZ is subdivided into the northern (NSVZ), transitional (TSVZ), central (CSVZ), and southern (SSVZ) segments based on petrographical and geochemical features of volcanic rocks and tectonic considerations (e.g., Hickey-Vargas et al., 2002). Although the petrographical and geochemical features of the volcanic rocks in the NSVZ and TSVZ are complex, the predominant magmatic products in the CSVZ and SSVZ are basalts and basaltic andesites, which exhibit similar petrographical and geochemical features in the region (Lopez-Escobar et al., 1993). The age of the subducting plate becomes younger from the CSVZ towards the SSVZ.
The fluorine and chlorine contents of the samples are 114–579 ppm and 41–820 ppm, respectively. Fluorine is positively correlated with other incompatible elements such as potassium, barium, uranium, and light to middle rare earth elements. In contrast, chlorine has no correlation with any incompatible elements. The along-arc variations of fluorine and chlorine showed different. Although the fluorine contents in the CSVZ and SSVZ are broadly constant, the samples from the southernmost SSVZ, situated near the CTJ, show high fluorine contents. On the other hand, the chlorine contents are high in the samples from the northernmost CSVZ and the southernmost SSVZ.
We estimated the melting conditions for the lavas based on the compositions of the incompatible element, except for halogens using an inversion mass balance calculation model proposed by Nakamura and Iwamori (2013). The fluorine and chlorine contents in the mantle source for the samples are inferred by the degree of partial melting obtained by the model calculation. The fluorine contents of the source mantle in the CSVZ and SSVZ are 24 ±7 ppm and 21 ±9 ppm, respectively, and there is no systematic geographical variation. The high fluorine contents in SSVZ are caused by a low degree of melting. Since the fluorine content of the depleted mantle (DM) is 16 ppm (Saal et al., 2002), our data indicates that the fluorine in the SVZ source mantle is derived almost solely from the wedge mantle with the DM composition. Previous studies (e.g., Spinelli et al., 2016) showed that the source mantle of the CSVZ and SSVZ are affected by aqueous fluids and sediment melt derived from the slab, respectively. However, the influence of the slab is not observed for fluorine in the source mantle. In case of chlorine, the contents of source mantle for the CSVZ and SSVZ are 36 ±28 ppm and 16 ±11 ppm, respectively, exhibiting marked enrichment relative to DM (1 ppm; Saal et al., 2002). This indicates that almost all the chlorine budget in the source mantle of the SVZ is attributed to the slab, and the contribution of the slab is greater in the

CSVZ than in the SSVZ. However, the variable chlorine contents in the SVZ lavas (and even within a single volcano) likely reflect the degassing process in the crust because the chlorine contents are very low relative to those in other arcs worldwide. Thus, the chlorine contents of source mantle and the contribution of the slab estimated by this work would indicate the minimum values.

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