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Analysis of fractionation process of the volcanic rocks based on principal component analysis with trace element

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Detailed information of fractionation process in the crust is a fundamental issue to discuss magma generation processes in the mantle and crust, and evolution of the mantle-crust system. Major element fractionation is non-linear process which involves thermodynamic relation. On the other hand, trace element processes can be regarded as linear process, because its partition coefficient between phases considered to be unity in many cases. Hence, trace element can be a good tracer for magma mixing and involvement of a particular phase (e.g., Depaolo, 1981). To discuss fractionation process in a multi-component and multi-phase system, multivariate statistics analysis is necessary. Here we employ a principal component analysis to analyze bulk compositional trends of series of lavas from quaternary Akita-komagatake and Hachimantai volcanoes in the Northeastern Japan arc to discuss fractionation process of each volcano. Based on the principal component analysis with trace element concentrations, and petrological analysis with the major element concentrations and mineralogy, we discuss a variation of fractionation processes in the crust and also propose a possibility of employing a principal component analysis to the volcanic process.

Three principal components account for the trace element variation of the Akita-komagatake volcano. The three principal components show correlation with the major element concentration, suggesting trace and major element processes are coupled in the Akita-komagatake volcano. The three principal components can be attributed to the various degree of closed system fractionation or accumulation of olivine, pyroxene and/or plagioclase. The result is consistent with the fractionation model based on analysis with the major element composition and mineralogy or calculation using MELTS (Ghiorso and Sack, 1995).

For the Hachimantai volcano, three principal components account for the trace element variation. The first principal component represents the two component process between relatively lithophile elements rich component and incompatible elements rich component. The third principal component represents indicates involvement of mantle derived Cr and Ni rich mafic component, as have been suggested in Ohba et al. (2009). The first and the third principal components show correlation with the major element concentration. The second principal component does not show any relationship between major element composition. The third trace element component may represent selective assimilation of trace element during melt/crustal rock interaction (Watson, 1982).

Result of this study demonstrate that multivariate statistics with trace element concentrations of volcanic rock can decompose multiple fractionation process in a single volcanic suite. Our result also suggests the existence of the decouple between major and trace element processes.

Keywords: Volcanic rock, Crystal fractionation, Magma mixing, Quaternary volcano, Fractionation process