Abstract

It is now widely accepted that the long-lived oceanic magmatism is a surface manifestation of “mantle plume”—narrow column of hot, buoyant, low-density material that flow upward from the deep region in the Earth’s mantle. The volcanic products of such magmatism could potentially give some important insights into the chemical and physical structure of the mantle plume, and its origin, evolution and dynamics occurring in the deep mantle through geological time. In my PhD study, I have been trying to understand the evolution of long-lived magmatism in order to give important insights into the chemical evolution and dynamics of the mantle plume. My PhD study focused on the temporal geochemical variations of the Icelandic magmatism. In order to understand the evolution of the Icelandic magmatism, I have been devoted to two main works: (1) analytical development for measurement of potassium in geological materials using an inductively coupled plasma mass spectrometry (ICP-MS) for K-Ar dating, which could be used to calibrate the history of the Icelandic magmatism, and (2) establishment of the detail petrological and geochemical record of the Icelandic magmatism during last 13 Myr for putting constrains on the nature of source materials contributing to magmatism and examining the evolution and dynamics of the Iceland mantle plume.

(1)

I report here a simple and rapid analytical technique to determine potassium concentrations in geological materials by utilizing an inductively coupled plasma mass spectrometer (ICP-MS) equipped with the collision reaction cell. The standard addition method was applied for the determination of potassium in the mass spectrometric procedure. The samples were digested with HF-$HClO_4$, followed by dissolution of potassium with 0.5 M HNO_3. This solution was further diluted with 0.5 M HNO_3 into dilution factor (DF) of ca. 3000. Three aliquots were made from this solution, and then the standard potassium stock solution (ca. 30 μg/g) was added into two aliquots in different amounts. In ICP-MS analysis, I found that the noises of 39 amu (atomic mass unit) derived from the argon-based polyatmic species were reduced by the positioning the torch far from the sampling orifice and introducing H_2 gas into the collision reaction cell. In the best analytical condition, the noise effect (noise/signal intensity ratio) on 39 amu could be suppressed below 0.01%. In this condition, the standard addition method for determination of potassium concentration was developed. First, the analyte signal intensities of ^{23}Na, ^{24}Mg, ^{25}Mg, ^{26}Mg, ^{27}Al, ^{39}K and ^{44}Ca, were measured for sample solutions, and then the ratios of ^{39}K/^{23}Na, ^{39}K/^{24}Mg, ^{39}K/^{25}Mg, ^{39}K/^{26}Mg, ^{39}K/^{27}Al and ^{39}K/^{44}Ca are calculated for the net intensities possessed by subtractions of the backgrounds. It is plotted on coordinates with ^{39}K/^{n}M (e.g. ^{23}Na) intensity ratio as the ordinate and standard/sample weight ratio as the abscissa. In this diagram, the three data for the sample should be plotted on the straight regression line. I usually could obtain well-correlated linear trends (R^2 values usually yield 0.999~1.000). At this time, the concentration of potassium in samples could be calculated from the absolute values of abscissa intercept of this regression line. To demonstrate the applicability of this method, some of the reference materials of the geological survey Japan (GSJ) were analyzed to obtain the potassium contents in these materials. The reproducibilities of < 1.5% for volcanic rock samples (basalts: JB-2 and JB-3; andesites: JA-2 and JA-3) were obtained and thus this method is considered to be usefully applicable to measurement of potassium in geological materials.

(2)

The first comprehensive geochemical (major and trace element concentrations) and Sr-Nd-Hf-Pb isotope data of the Tertiary lavas from eastern Iceland, ranging in age from ca. 13 to < 1 Ma, together with published geological, geochronological and geophysical data, are used to evaluate the temporal changes in mantle sources contributing to the Icelandic Tertiary magmatism and their relative roles on magma productivity. The trace element and isotopic composition could clearly discriminate the involvement of three distinct mantle end-components in the Icelandic Tertiary magmatism. The temporal variation in lava geochemistry is attributed to the changes

in relative contribution of these three end-components to the erupted magma. I found that the temporal variation of magma productivity is well correlated with the lava geochemistry. The extrusion of lavas with geochemically enriched composition is marked in the periods of 13-11 and 8-7 Ma, which are coincident in time with higher magma productivity. However, the geochemical characteristics of lavas erupted among these two discrete periods are quite different. The lavas of the former period have relatively more radiogenic ^{176}Hf/^{177}Hf and less radiogenic ^{206}Pb/^{204}Pb ratios than those produced during the latter period. The extrusion of relatively depleted lavas around 10 Ma and younger than 6.5 Ma are coincident with lower magma productivities. The coincidence of the productivity and compositions of the Icelandic Tertiary lavas could be interpreted that the periodic involvement of geochemically enriched end-component and subsequent participation of depleted end-component in magma generation with ca. 4 Myr intervals as the progress of magmatism. This periodicity may be controlled by thermochemical interactions induced by the presence of dense recycled crustal materials in the plume source region at the thermal boundary layer in deep mantle.