

## Development of an analytical method for stable isotope geochemistry of rare earth elements

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The study of naturally occurring isotopic variations of rare earth elements (REEs) has a potentially significant influence in geochemical research fields. One of the key features of REEs are their chemical similarities and gradual changes of ionic radius, which may make the isotopic variation of REEs a potential tool to understand the mechanisms of isotopic fractionation in nature. Among the REE, geochemical and physicochemical features of Ce could be anomalous, because Ce could be present as the tetravalent (+IV) state as well as the common trivalent (+III) state of other REE. Since the oxidation state of Ce can change by reflecting the redox conditions of the environment, the measured differences in the degree of isotopic fractionation between Ce and other REE can provide unique information about the redox conditions of the geochemical background.

In this study, we developed a new analytical method to determine the mass-dependent isotopic fractionations of Ce, Nd, Sm, Eu, Gd, Dy, Er, and Yb in geochemical samples using MC-ICP-MS. The present technique was applied to determine the variations of the Ce and Nd isotopic ratios for five geochemical reference materials (igneous rocks: JB-1a and JA-2; sedimentary rocks: JMn-1, JCh-1 and JDo-1). The resulting ratios for two igneous rocks (JB-1a and JA-2) and two sedimentary rocks (JMn-1 and JCh-1) did not vary significantly among the samples, whereas the Ce and Nd isotope ratios for the carbonate sample (JDo-1) were significantly higher than those for igneous and sedimentary rock samples. The isotope ratios of Sm, Eu, Gd, Dy, Er, and Yb for the carbonate sample (JDo-1) were also higher than those for the manganese nodule sample (JMn-1). There were no significant difference in the degree of isotopic fractionation among the REE. This suggests that the isotopic fractionation for Ce in the JDo-1 could be induced by physicochemical processes without changing the oxidation status of Ce, since the redox-reaction can produce larger isotopic fractionation than the reactions without changing the oxidation state. The isotopic variations in the REE for geochemical samples could provide new information concerning the physico-chemical processes of the sample formation.