博士学位論文の要約

論文題目

Cosmochemical study on the heterogeneity and diversity of nucleosynthetic components in the early solar system inferred from Ba and Sr isotopic analyses of primitive planetary materials

(始原惑星物質中の Ba および Sr 同位体分析からみた初期太陽系の原子核合成成分の不均質性と多様性に関する宇宙化学的研究)

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The purpose of this study is to elucidate the heterogeneity and diversity of nucleosynthetic components in the early solar system based on Ba and Sr isotopic analyses of primitive planetary materials.

Ba and Sr are suitable elements for the isotopic study to infer the origin and diversity of nucleosynthetic components because of their specific nuclear signatures. Elements heavier than Fe are synthesized mainly by the s-process (slow neutron capture), the r-process (rapid neutron capture), and the p-process (photodissociation of nuclides). Ba and Sr isotopes consist of s-, r- and p-process isotopes. In addition, ^{135}Ba and ^{87}Sr include radiogenic components decayed from ^{135}Cs ($t_{1/2}$ = 2.3 Ma) and ^{87}Rb ($t_{1/2}$ = 4.88 Ga), respectively. Therefore, isotopic studies of Ba and Sr in primitive planetary materials led to the evaluation of isotopic heterogeneity in the solar system, and may be applied to the chronological study based on ^{135}Cs–^{135}Ba and ^{87}Rb–^{87}Sr decay systems. In this study, isotopic analyses of Ba and Sr, and quantitative analyses of Rb, Sr, Cs, Ba and rare earth element (REE) abundances from the chemical separates obtained from sequential acid leaching experiments of five carbonaceous chondrites, Cold Bokkeveld, Murray, Nogoya, NWA 4428, and Tagish Lake, were performed to discuss the heterogeneity and diversity of nucleosynthetic components in the early solar system.

Each of the powdered samples (400–1000 mg) was used in this study. To assess the origin of isotopic anomalies in primitive planetary materials, a sequential acid-leaching experiment was performed. The majority of each of the powdered samples was leached using 0.1 M CH_3COOH-CH_3COONH_4, 0.1 M HCl, 2 M HCl, and aqua regia, successively. The acid residue was finally decomposed by HF–$HClO_4$. Separately from the above leaching treatment, the rest of the powdered sample was decomposed by HF–$HClO_4$, and treated as a whole rock (WR) for analysis. Each fraction was evaporated to dryness, and redissolved in 2 M HCl. The solution was divided into two portions; a major portion for Sr and Ba isotopic analyses by thermal ionization mass spectrometry (TIMS) and another minor portion for the determination of elemental abundances of Rb, Sr, Cs, Ba, and REEs by inductively coupled plasma mass spectrometry (ICP-MS). Each major portion was used for the isotopic studies after chemical separation with conventional resin chemistry.

The Ba and Sr isotopic data of WRs of carbonaceous chondrites often show a slight difference in their isotopic compositions compared with those of terrestrial materials (nucleosynthetic isotopic anomalies). On the other hand, the Ba and Sr isotopic data from most of the chemical separates of the carbonaceous chondrites show larger nucleosynthetic isotopic anomalies than those of the WRs. These Sr and Ba isotopic data set suggest a heterogeneous distribution of several nucleosynthetic components in the early solar system. The chemical separates obtained by the sequential acid-leaching experiment are suitable for the consideration of several factors contributing to isotopic anomalies in the primitive planetary material that cannot be detected by analyses of WR alone.

The Ba isotopic data for the acid residues in all carbonaceous chondrites show significant isotopic anomalies because of the enrichment of presolar SiC grains, which is a representative carrier of s-process isotopes. Furthermore, the correlation between the isotopic data for ^{135}Ba, ^{137}Ba, and ^{138}Ba for the acid residues in Cold Bokkeveld, Murray, and Nogoya suggests the contribution of presolar X grains (n-process components), which are thought to come from type II Supernova. In order to discuss the ^{135}Cs isotopic abundance, two new models were proposed in which the contribution of s- and n-process nucleosynthetic components is subtracted from the isotopic compositions of the acid residues.

The chemical separates of carbonaceous chondrites used in this study show isotopic anomalies of ^{84}Sr, ^{130}Ba, and ^{132}Ba, which are p-process isotopes. On the other hand, these isotopic anomalies of ^{84}Sr, ^{130}Ba, and ^{132}Ba suggest that the apparent isotopic anomalies were caused by the false correction of the instrumental mass fractionation in association with the addition of s-process isotopes. Furthermore, the isotopic deficits of ^{84}Sr, ^{130}Ba, and ^{132}Ba observed in the acid residue in carbonaceous chondrites may be caused by the presence of presolar SiC grains.

The Tagish Lake meteorite may originate from the same parent body/ies as the CM chondrite, this possibility was discussed based on the comparison of the elemental and isotopic data of Tagish Lake and CM chondrites obtained in this study. Isotopic data of Sr and Ba for the Tagish Lake meteorite were similar to those for CM. In particular, the Ba isotopic data of the acid residues in all carbonaceous chondrites confirmed the isotopic anomalies mainly due to the presence of presolar SiC grains.