【Grant-in-Aid for Scientific Research (S)】

Elucidation of the origin of the aqua-planet Earth from isotope anomaly in Hadean

Principal Investigator	Gakushuin University, Faculty of Science, Professor OHNO Takeshi　　Researcher Number : 40452007
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Purpose and Background of the Research

●Outline of the Research

Recent advances in precise chemical analyses of meteorites have led to the idea that an aqua-planet Earth was formed by a mixture of rocky materials close to the sun and materials containing ice from further away from the sun. Understanding this mixing process is linked to the answer to the question of “how and when did Earth become an aqua-planet?

In the early stages of the Earth's formation, mantle convection known as the stagnant-lid type (Fig. 1), similar to that of Venus and Mars, was driving the Earth's surface, and that hotspot-type magma was erupting on the Earth's surface. On the other hand, when the oceans formed on the Earth's surface, it is thought that plate tectonics was driven, and furthermore, water was supplied to the mantle through subduction zones, and continental crust-type magma was generated (Fig. 2), however there is a lack of evidence to discuss these changes.

In this study, in order to elucidate how and when the Earth became an aqua-planet, we plan to determine the initiation of plate tectonics, which characterizes the aqua-planet Earth, by analyzing the formation age and trace element composition of the oldest minerals on Earth, Hadean zircons. In addition, in order to clarify the origin of the material that brought water to Earth, we plan to analyze the zirconium isotopic composition in the Hadean zircons and the ruthenium isotopic composition in the oldest rocks on Earth, and investigate the process by which the Earth evolved from a rocky planet to a watery planet.

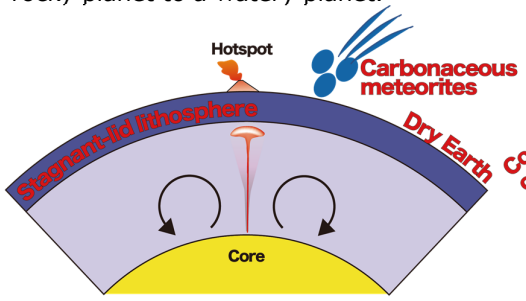

Figure 1. Stagnant lid-type mantle convection

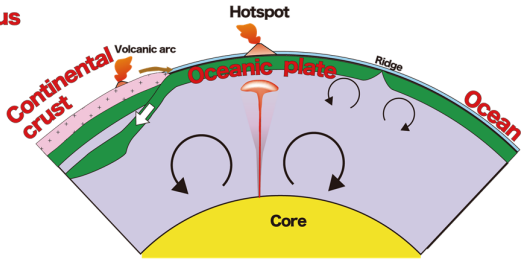

Figure 2. Plate tectonics-type mantle convection

●Deciphering the Initiation of plate tectonics from the Hadean zircon

Zircons incorporate radioactive elements such as uranium when it crystallizes from magma, so by examining the proportion of lead produced by radioactive decay, it is possible to determine the age of the zircon from a single grain of zircons. Zircons also contain various trace elements. By clarifying the relationship between the elemental distribution of the magma and zircons, it is also possible to extract information about the host magma from the trace element composition of the zircons.

●Isotopic anomalies in Hadean

Recent precision chemical analyses of meteorites have revealed that the isotope ratios of ruthenium-100 in rocks from 3.8 billion years ago show isotope anomalies that are more similar to those of the region closer to the Sun than the enstatite chondrites (EC) meteorites and the Earth's surface today. These results suggest that the Earth was formed from asteroids closer to the Sun than the EC meteorites.

Recent research has reported the existence of an isotopic anomaly in zirconium-96 between EC meteorites and carbonaceous meteorites. If material containing water and organic matter that was located away from the sun in the Hadean era mixed with the rocky planet Earth, this process could be traced by deciphering the changes in the isotopic anomalies of zirconium-96 in Hadean zircons and ruthenium-100 in 3.9 billion years old rock samples using MC-ICP-MS.

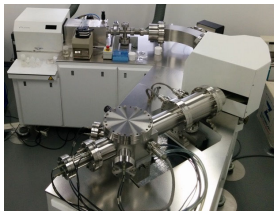

Figure 3. MC-ICP-MS

Expected Research Achievements

●Search for Hadean minerals

We have extracted zircons from Jack Hills rock samples in Australia and analyzed about 10,000 grains. In this research, we will search for samples from multiple regions, including Barberton in South Africa and Labrador in Canada, and aim to decipher global changes. In this research, the rapid and large-scale analysis for zircon dating will play an important role in the early stages of the research. We will improve the rapid zircon separation method by using a low vacuum SEM. We will also improve the speed of screening dating methods and the sensitivity of trace element analysis methods. We will develop a high-precision dating method using a next-generation multiple collector inductively coupled plasma mass spectrometer.

●Estimation for the host rock of Hadean zircons

In order to investigate the period when plate tectonics began, we will determine the timing of of the formation of the continental crust using the trace element composition (Sc/Yb, Nb/Yb, Ta/P, Ce/P) of Hadean zircons. In this study, we will develop a more accurate host rock estimation method by analyzing zircons that crystallized from continental crust magma originating from subduction zones and zircons contained in the hotspot-type magma from Hawaii and Iceland. Using these analytical methods, We will investigate the period when the Hadean zircons was produced only from the hotspot-type magma. We will also clarify the period when it began to be produced from the magma of the continental crust generated from the subduction zone.

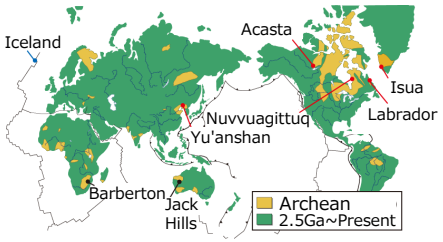

Figure 4. Research area

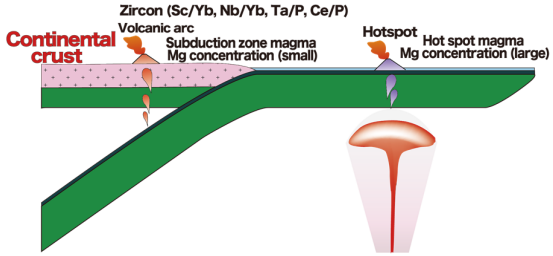

Figure 5. Detrital zircon analysis for host rock estimation

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