

Geochemical characteristics and U-Pb age of metamorphic zircons from Estherville: constraints on the timing of mesosiderite formation. M. K. Haba¹, A. Yamaguchi¹, H. Kagi², K. Nagao², and H. Hidaka³, ¹National Institute of Polar Research, Tachikawa, Tokyo 190-8518, Japan, ²Geochemical Research Center, University of Tokyo, Bunkyo-ku, Tokyo 113-0033, Japan, ³Department of Earth and Planetary Systems Science, Higashi-Hiroshima, Hiroshima 739-8526, Japan.

Introduction:

Zircons (ZrSiO_4) from asteroids have been found in basaltic eucrites [e.g., 1–3], a mesosiderite [4], and an H5 chondrite [4]. Zircon has strong resistance to thermal annealing compared to the other constituent minerals in meteorites. In addition, they are suitable for U-Pb and ^{182}Hf - ^{182}W dating due to moderate contents of U and Hf and low contents of their daughter nuclides. Therefore, zircons from asteroidal meteorites are very important for determining the timing of thermal events on their parent bodies.

The ^{207}Pb - ^{206}Pb ages of zircons from basaltic eucrites have clustered at ~ 4550 Ma [1,2], and that of one zircon from Vaca Muerta mesosiderite is 4563 ± 15 Ma [4]. These ^{207}Pb - ^{206}Pb ages have been considered to correspond the formation age of zircons during magmatism on the parent bodies. However, recent studies have revealed that zircons from highly metamorphosed eucrites could have formed and/or overgrown during subsolidus reheating events. [3,5]. This formation process of the metamorphic zircons in eucrites could be applied for zircons in mesosiderites because mesosiderites contain some basaltic clasts and had experienced a significant crustal remelting.

In this study, we analyzed zircons found in the highly metamorphic Estherville mesosiderite (3–4A) to investigate an internal texture, chemical compositions, and a U-Pb age. Based on the results from *in-situ* analyses, we will describe the formation process of zircons in mesosiderites and correlate the U-Pb age of zircons with the thermal events which occurred on the mesosiderite parent body.

Sample and methods:

The sliced Estherville samples (10 by 10 by 1 mm) were mounted on an acrylic resin disk and polished with $1/4 \mu\text{m}$ diamond paste. Zircons in the samples were identified by an elemental mapping of Zr using an electron probe micro-analyzer (EPMA) (JEOL JXA 8200) at the National Institute of Polar Research (NIPR). A scanning electron microscope-cathodoluminescence (CL) at Hiroshima University was used to obtain a back-scattered electron (BSE) image and a CL image of individual zircon grains (Fig. 1). The quantitative analysis of major and minor elements of zircons was conducted using EPMA. A sensitive high-resolution ion micro-probe (SHRIMP IIe) at Hiroshima University was used for obtaining rare earth element (REE)

contents and U-Pb age of the zircons.

Results:

The grain size of one zircon is $30 \times 100 \mu\text{m}$ (Zircon1) and the other is $100 \times 300 \mu\text{m}$ (Zircon2) (Fig. 1). Most of the zircons from basaltic eucrites, mesosiderite, and H chondrite are less than $10 \mu\text{m}$, and the maximum size is about $30\text{--}40 \mu\text{m}$ [1–5]. Compared to them, the two zircons found in Estherville mesosiderite are remarkably large. The CL images show that Zircon1 has homogeneous internal texture. On the other hand, Zircon2 has obvious heterogeneous internal texture, and a part of it is bright in the BSE image and dark in the CL image compared to the other area.

The Zr/Hf ratios of Zircon1 are 60.6–69.0 wt.%, which is higher than that of the zircon from Vaca Muerta mesosiderite (Zr/Hf = 52.7 [4]) and the chondritic value (Zr/Hf = 32.8–34.3 [6,7]). On the other hand, the Zr/Hf ratios of Zircon2 show a large variation ranging from 48.6 to 112.1. The large variation indicates that Zircon2 is composed of chemically heterogeneous domains.

The CI-normalized REE patterns of Zircon2 are shown in Fig. 2. The REE patterns of the three analytical points in Zircon2 show upward REE patterns and distinct negative Eu anomalies as well as those of zircons in basaltic eucrites. The REE contents of the analytical spot 1 are about $\text{La} = 0.1 \times \text{CI}$ and $\text{Lu} = 1000 \times \text{CI}$, which fall within the range of REE contents of the eucritic zircons. On the other hand, the REE contents of the analytical spots 2 and 4 are $\text{La} = 0.1 \times \text{CI}$ and $\text{Lu} = 200 \times \text{CI}$, and $\text{La} = 0.06 \times \text{CI}$ and $\text{Lu} = 90 \times \text{CI}$, respectively. The degree of Eu anomaly of Zircon2 largely varies even in the single-grain.

U and Th contents of two points in Zircon1 and four points in Zircon2 were determined. The analytical spot 1 in Zircon2 (Fig. 3) has clearly higher U and Th contents (48.5 ppm and 42.9 ppm, respectively) than the other analytical spots in Zircon1 and Zircon2. The U and Th contents of Zircon2 decrease in proportion with the distance from the analytical spot 1 (Fig. 3). This tendency is also observed on REE contents in Zircon2.

The U-Pb analysis was performed on two analytical spots in Zircon2 (analytical spot 1 and 2 in Fig. 3). The radiogenic $^{207}\text{Pb}/^{206}\text{Pb}$ ratios of the two analytical spots are well consistent around ~ 0.6 . The weight average ^{207}Pb - ^{206}Pb age of Zircon2 is 4520 ± 27 Ma.

Discussion:

In-situ analyses performed on the zircons revealed that there are two types of zircon in Estherville mesosiderite. One is the zircon that corresponds to the dotted area in Fig. 1, which has similar chemical compositions to eucritic zircons. Most of the eucritic zircons have been recognized to form during magmatism and/or subsolidus metamorphism on the parent body. Therefore, this type of zircon is considered to be the relict zircon that could form on the parent body of silicate parts in mesosiderites. On the other hand, the other area in Zircon1 and Zircon2 have extremely low REE, U, and Th contents compared to those of the relict part in Zircon2 and the eucritic zircons. Similar zircon having low REE, U, and Th contents have been observed in Vaca Muerta mesosiderite (VM-2 (U = 0.58 ppm, Th = 0.051 ppm)) [4]. Therefore, this type of zircon is probably unique to mesosiderites and could have formed during the significant crustal remelting which exceeded the solidus temperature.

The distributions of REE, U, and Th in Zircon2 strongly suggest REE, U, and Th in the relict zircon diffused to or mixed with the newly formed part during the crustal remelting. Since Pb is incompatible in the Zircon crystal structure and the diffusion rate in zircon is several orders of magnitude faster than those of U and Th, Pb must have migrated from the relict part. In that case, the U-Pb decay system in the relict part could be reset during the crustal remelting, which indicates the timing of the metal-silicate mixing event that probably caused the crustal remelting and formed mesosiderite. The ^{207}Pb - ^{206}Pb age (4520 ± 27 Ma) determined from Zircon2 is within the range of the formation age of mesosiderites inferred from the previous works (4470–4548 Ma [8,9]). Therefore, the ^{207}Pb - ^{206}Pb age of the zircon in Estherville mesosiderite is considered to correspond to the timing of the mesosiderite formation.

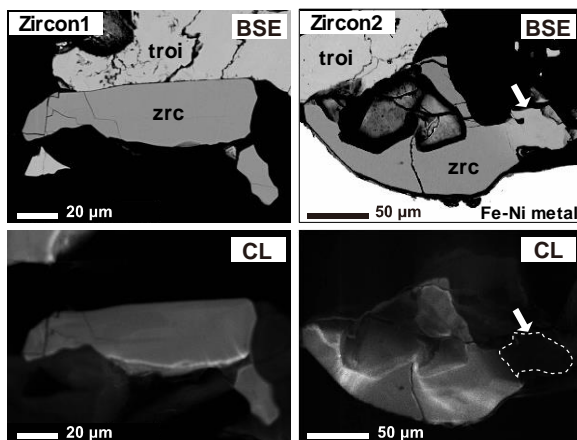


Fig. 1. BSE and CL images of zircons found in Estherville mesosiderite. zrc = zircon and troi = troilite.

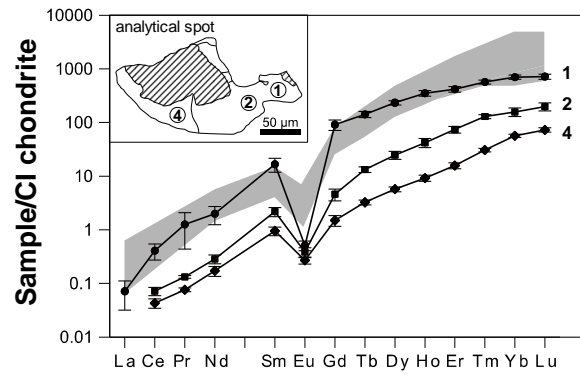


Fig. 2. CI-normalized REE patterns of three analytical spots in Zircon2. The gray field shows REE patterns of zircons from basaltic eucrites [3].

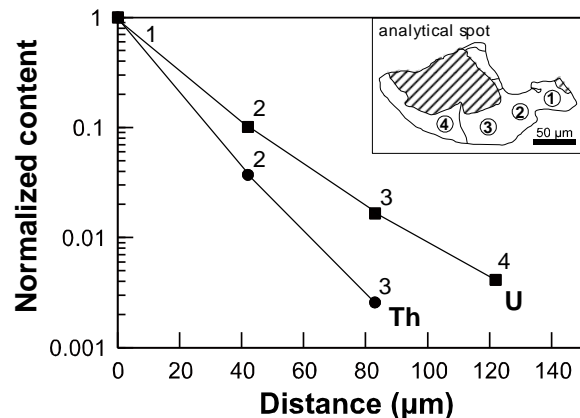


Fig. 3. U and Th contents in each analytical spot in Zircon2. The contents are shown as the normalized content by the U and Th contents of the analytical spot 1. The normalized U and Th contents of each analytical spot are plotted against the distance from the analytical spot 1.

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