Determination of the age of the metal-silicate mixing on the mesosiderite parent body

*Makiko K. Haba[1], Akira Yamaguchi[2], Yi-Jen Lai[3], Jörn-Frederik Wotzlaw[3], Maria Schönbächler[3]

1. Department of Earth and Planetary Sciences, Tokyo Institute of Technology, 2. National Institute of Polar Research, 3. ETH Zurich

Mesosiderites are polymict breccias composed of roughly equal amounts of silicates, which are similar to HED meteorites, and Fe-Ni metal. This meteorite group has been thought to have formed by mixing of crustal and core materials without including much of the mantle. Although several scenarios have been proposed for the metal-silicate mixing, the origin of Fe-Ni metal that was molten at that time and the mechanism of the mixing event are still open questions. Therefore, a well-constrained age of the metal-silicate mixing is important information to improve our understanding of the formation process of mesosiderites. Although the Sm–Nd and Mn–Cr ages of mesosiderites have revealed that the metal-silicate mixing occurred 20–150 Ma after the solar system formation (Stewart et al., 1994; Wadhwa et al., 2003), the age still has a large range more than 100 million years. In order to determine a more precise age of the metal-silicate mixing event, it is necessary to analyze the minerals which had formed during the mixing event. Also, it is necessary that the sample has remained closed systems for chronometers throughout the later impact events. In this study, we present the ^{92}Nb-^{92}Zr and U-Pb ages of mesosideritic rutiles and zircons in consideration of the formation mechanisms of the minerals. The goal of this study is to determine the age of the metal-silicate mixing event that formed mesosiderites.

Four mesosiderites having different metamorphic grades, Vaca Muerta (1A), NWA 1242 (2A), A 882023 (2/3A), and Estherville (3/4A), were used in this study. Rutiles and zircons were separated from residual samples after dissolving the metal parts and silicate parts with concentrated acids. Subsequently, rutile grains were dissolved in HNO_3-HF using Parr® bombs. The Nb/Zr ratio and Zr isotope measurements were performed using a quadrupole ICPMS and a Neptune Plus MC-ICPMS, respectively, at ETH Zurich. Four individual zircons (70–200 μm in diameter) were spiked with 3–5 mg of EARTHTIME ^{202}Pb-^{205}Pb-^{233}U-^{235}U tracer solution and dissolved in concentrated HF using Parr® bombs. U and Pb were separated using a HCl-based column chemistry and measured using a TRITON Plus TIMS at ETH Zurich.

The rutiles from each sample yielded ^{93}Nb/^{90}Zr ratios of 12.7 ±0.8 in Vaca Muerta, 9.9 ±0.4 in NWA 1242, 1.61 ±0.12 in A 882023, and 1.26 ±0.08 in Estherville. The ^{93}Nb/^{90}Zr ratios decrease with increasing metamorphic grades of our samples from Vaca Muerta (1A) to NWA 1242 (2A), A 882023 (2/3A), and Estherville (3/4A). Since the metamorphic grades of mesosiderites were established during the metal-silicate mixing event (e.g., Delaney et al., 1981), the rutiles likely formed during this event. The Nb-Zr data from rutiles are plotted on a single isochron line (Fig. 1), which indicates that the ^{92}Nb-^{92}Zr decay system of mesosideritic rutiles has not been disturbed by later impacts after they formed during the metal-silicate mixing event. Using the initial ^{92}Nb/^{93}Nb ratio of rutiles ((7.5 ±0.7) ×10^{-6}) and the solar system initial ^{92}Nb/^{93}Nb ratio from Iizuka et al. (2016), the ^{92}Nb-^{92}Zr age of rutiles was calculated to be 44 ±16 Myr after CAI. This age corresponds to the absolute age of 4524 Ma.

According to Haba et al. (2015), mesosiderites have two kinds of zircons: (I) relict zircons that crystallized before the mixing event, and (II) secondary zircons that formed through the mixing event. Typical secondary zircons show quite low U (~0.3 ppm) and Th (~0.04 ppm) contents because they formed after the incorporation of U, Th, and REE into abundant phosphate minerals. All zircon grains measured in this study have very low U contents, which indicate that they are secondary zircons, and yielded a weighted mean ^{207}Pb-^{206}Pb age of 4528.4 ±1.4 Ma (2σ). This age is in good agreement with the ^{92}Nb-^{92}Zr age of rutiles. Therefore, the metal-silicate mixing event that formed mesosiderites is considered to have

©2017. Japan Geoscience Union. All Right Reserved.

occurred at 4528.4 ±1.4 Ma.

Keywords: mesosiderites, metal-silicate mixing event, radiometric dating, zircon, rutile

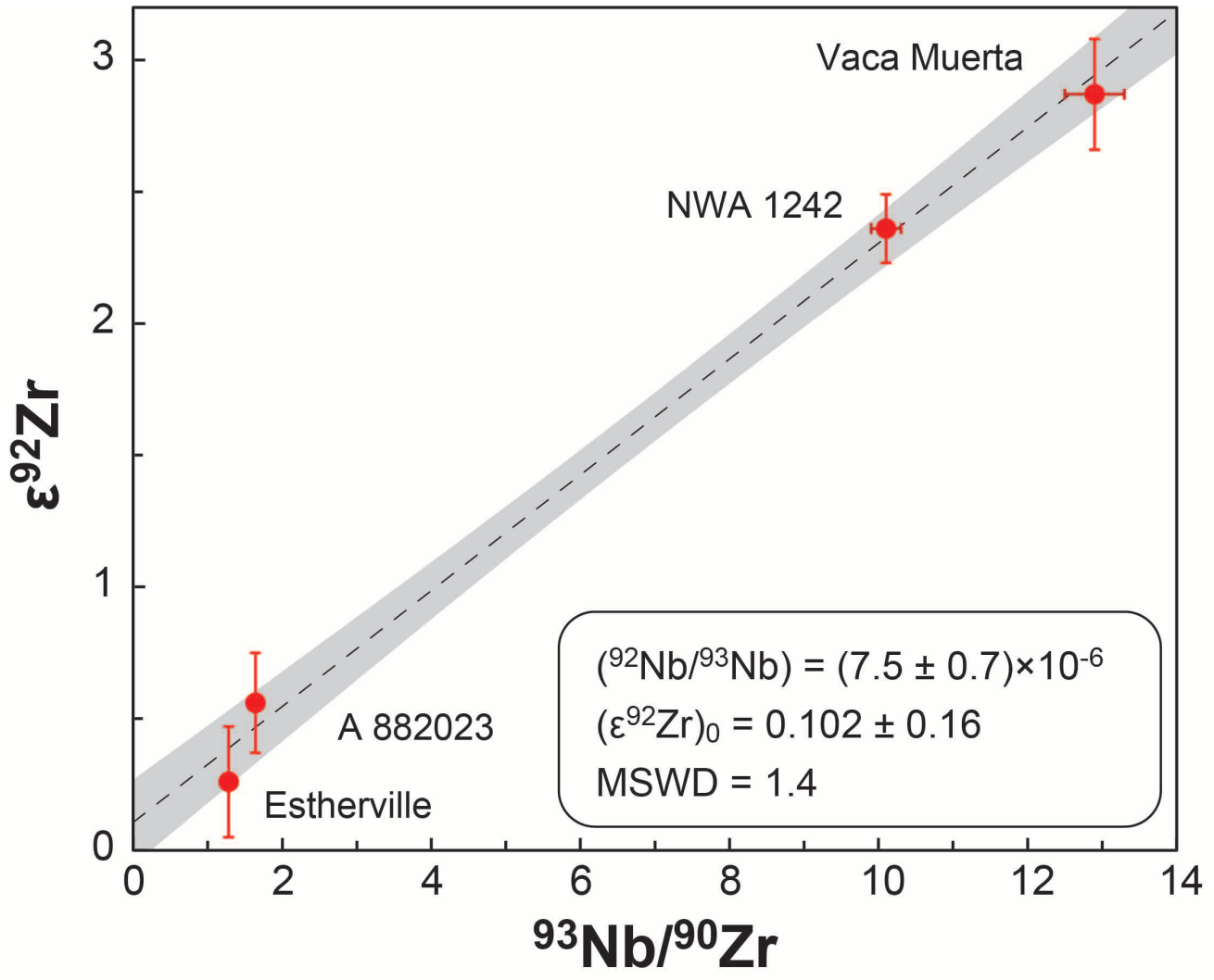

Fig. 1. Nb-Zr isochron diagram for mesosideritic rutiles. The isochron regression and error envelope (95% probability) are shown as a dotted line and gray area, respectively. The data-point errors are 2 σ.

©2017. Japan Geoscience Union. All Right Reserved.