

Zr isotope constraints on early Earth differentiation

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The radionuclide ^{92}Nb decays to ^{92}Zr with a half-life of 37 Ma [1]. Because Nb and Zr can fractionate from each other during partial melting of the mantle and mineral crystallization as well as metal-silicate differentiation, Nb-Zr isotope systematics can potentially place chronological constraints on early planetary differentiation. Considering the initial abundance of ^{92}Nb in the solar system ($^{92}\text{Nb}/^{93}\text{Nb} = 1.7 \times 10^{-5}$), yet, the possible Zr isotopic variation on the Earth would be highly restricted [2]. For instance, even a 4.53 Ga reservoir having a Nb/Zr ratio four times higher than that of CHUR is expected to display a ^{92}Zr anomaly of only +10 ppm. Such reservoir with an elevated Nb/Zr ratio might be formed if Fe-Ti oxide and sulfide minerals presented as a liquidus phase during differentiation on the infant Earth.

Here we report our search for a Zr isotopic vestige of early Earth differentiation using ancient terrestrial zircons. Zirconium isotopic ratios in single zircon grains were measured using MC-ICP-MS with the desolvating nebulization technique, which allows us to achieve analytical precision of ± 10 ppm. So far, the high-precision Zr isotopic analysis has been applied to detrital zircons with ages up to 4.3 Ga from the Jack Hills in the Yilgarn Craton, Western Australia and igneous zircons from the 4.0–3.6 Ga orthogneisses in the Acasta Gneiss Complex, northwestern Canada. These Acasta rock samples were previously studied for zircon Lu–Hf isotope systematics and the results indicated that their magmatic sources contained Hadean crustal components [3]. Our Zr isotopic data for the Jack Hills and Acasta zircons display no ^{92}Zr anomalies larger than 10 ppm. By combining the Hf isotopic data for these zircon grain, we indicate the development of a 4.5 Ga enriched reservoir on the Earth that had a Lu/Hf of 0.07 and a Nb/Zr less than 0.4. Such reservoir could form via fractional crystallization processes within the shallow or upper mantle. [1] Holden (1990) Pure Appl. Chem. 62, 941–958. [2] Iizuka et al. (2016) Earth Planet. Sci. Lett. 439, 172–181. [3] Iizuka et al. (2009) Chem. Geol. 259, 230–239.

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