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The Hf isotope evolution of the bulk silicate Earth: Evidence from meteorite zircon

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The ^{176}Lu-^{176}Hf radioactive decay system has been widely used to constrain the timescales and mechanisms of Earth's crust-mantle differentiation, but the interpretation of Lu-Hf isotope data requires an accurate estimation of Hf isotope evolution of the bulk silicate Earth (BSE). Because both Lu and Hf are refractory and lithophile, the isotope evolution can be potentially reconstructed from the present-day ^{176}Hf/^{177}Hf and ^{176}Lu/^{177}Hf in undifferentiated chondrite meteorites. Unfortunately, however, these ratios in chondrites are highly variable due to the metamorphic re-distribution of Lu and Hf, making it difficult to ascertain the correct reference values for the BSE. In addition, it has been proposed that chondrites contain excess ^{176}Hf due to the accelerated decay of ^{176}Lu resulting from photoexcitation to a short-lived isomer in the early Solar System. If so, the paradigm of a chondritic BSE would no longer be valid for the Lu-Hf system. Herein we report the first high-precision Lu-Hf isotope analysis of meteorite zircon, a mineral that is resistant to metamorphism and has low Lu/Hf. The analyzed zircon grains were extracted from the non-cumulate eucrite Agoult. Based on the zircon Lu-Hf isotope data as well as the Agoult whole-rock Lu isotope data, we determine the initial ^{176}Hf/^{177}Hf of the Solar System to be 0.279791 +/- 0.000018. Reconciling the Solar System initial ^{176}Hf/^{177}Hf value with Lu-Hf isotope systematics of chondrites indicates a constant decay rate of ^{176}Lu throughout the history of the Solar System, thereby removing the requirement for a non-chondritic BSE. We further use the initial value to identify chondrites that preserve the primary Lu-Hf signatures and, therefore, are the best representative of the BSE. Our newly established Lu-Hf parameters for the BSE (^{176}Hf/^{177}Hf = 0.282793 +/- 0.000011; ^{176}Lu/^{177}Hf = 0.0338 +/- 0.0001) strengthen the evidence that the most primitive Hf in terrestrial zircon reflects the development of a chemically enriched silicate reservoir on Earth as early as 4.5 billion years ago on Earth.

Keywords: bulk silicate Earth, zircon, hafnium isotopes, crust-mantle differentiation, eucrite, early solar system