Constraints from the $^{92}\text{Nb} - ^{92}\text{Zr}$ chronometer on the timing of early terrestrial silicate differentiation

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It is evident that early global differentiation of the silicate Earth occurred more than 4.47 Gyr ago based on the extinct $^{146}\text{Sm} - ^{142}\text{Nd}$ chronometer [1, 2]. The short-lived $^{92}\text{Nb} - ^{92}\text{Zr}$ decay system (half-life of 36 Myr) is another excellent tool for dating early silicate differentiation owing to the different compatibilities of Nb and Zr during magmatic processes. Although its half-life is about one third of that of $^{146}\text{Sm} - ^{142}\text{Nd}$, Nb/Zr fractionation is likely an order of magnitude higher than for Sm/Nd during silicate differentiation [3]. Therefore, the Nb-Zr chronometer has the potential to better constrain the timing of the earliest silicate differentiation.

High-precision Zr isotope data of 10 Archean rocks (8 amphibolite and 2 dyke samples) from the Isua Supracrustal Belt were obtained. These samples exhibit well-resolved variations in $^{142}\text{Nd}/^{144}\text{Nd}$, indicating that they inherited this signature from their sources that formed more than 4.47 Ga [2]. The Zr isotope ratios were measured on a Neptune Plus MC-ICPMS at ETH Zürich. The average $\varepsilon^{92}\text{Zr}$ value, and associated external precision (2SE) of this technique [4] for the USGS basalt BHVO-2 is $0.00 \pm 0.02$ ($n = 56$).

The samples from the Isua Supracrustal Belt show no resolvable variation in $\varepsilon^{92}\text{Zr}$. They yield an average $\varepsilon^{92}\text{Zr}$ of $0.00 \pm 0.05$ (2SD) for the amphibolites and $0.04 \pm 0.05$ (2SD) for the dykes. This indicates that early silicate differentiation preserved in these samples occurred later than 20 - 60 Myr after the formation of the first solids in the solar system, assuming that the Earth’s Nb/Zr ratio is the same as chondrites and the initial solar system $^{92}\text{Nb}/^{89}\text{Nb}$ is between $(2.5 - 5.3) \times 10^{-5}$ based on internal isochrons of the achondrites [5]. Combining evidence from the $^{146}\text{Sm} - ^{142}\text{Nd}$ and $^{92}\text{Nb} - ^{92}\text{Zr}$ chronometer indicates that silicate differentiation for the Isua mantle reservoir occurred 4.51 - 4.47 Gyr ago.