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The zirconium isotope composition of the mantle and upper continental crust through time

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Zirconium isotopes have the potential to trace both magmatic differentiation and crustal evolution, as well as deep Earth processes. We report the Zr isotopic composition of 31 komatiites from different global localities, spanning ages between 2.41 - 3.55 Ga, and 38 sedimentary samples/composites of the upper continental crust (UCC), including 12 Holocene loess from China, three oceanic sediments from the sea floor outboard of the Lesser Antilles island arc and 23 glacial diamictite composites with depositional ages ranging from ~ 2.9 Ga to 0.3 Ga. We use these samples to estimate the zirconium isotopic composition of the mantle and UCC through time. The average $\delta^{94/90}Zr_{IPGP\text{-}Zr}$ (per mille deviation of $^{94}Zr/^{90}Zr$ from IPGP-Zr standard) value for the komatiites is 0.030 ± 0.049 (2SD) ‰ and is similar to that of the associated basaltic rocks (0.048 ± 0.032 ‰, 2SD). By combining the isotopic compositions of komatiites and basalts of all ages we estimated an average $\delta^{94/90}Zr_{IPGP\text{-}Zr}$ of 0.040 ± 0.044 (2SD)‰ for Earth's mantle. All sedimentary samples have constant $\delta^{94/90}Zr_{IPGP\text{-}Zr}$ values regardless of their depositional ages and locations. Therefore, the UCC appears to have maintained a constant Zr isotopic composition between 3 Ga and present, and has been homogeneous on the global large scale. Combining data for sedimentary reference materials from the literature and the sedimentary samples in this study, we calculate a $\delta^{94/90}Zr_{IPGP\text{-}Zr}$ value of 0.077 ± 0.058‰ (2SD, n = 44) for the UCC, which is statistically distinct from (t test, p value = 7.97×10^{-10}) and higher than that of the mantle estimate (0.040 ± 0.044‰, n = 72). We interpret this offset to be specific to the felsic bulk composition of the UCC, as evolved igneous rocks have been shown to have higher $\delta^{94/90}Zr_{IPGP\text{-}Zr}$ values compared to mafic rocks (from 0.053 to 0.475‰ based on the $\delta^{94/90}Zr_{IPGP\text{-}Zr}$ of granitoid rocks). Given the felsic nature of the UCC (average 66.6 wt.% SiO_2), and the only slightly elevated $\delta^{94/90}Zr_{IPGP\text{-}Zr}$ value of UCC relative to that of the mantle, this likely reflects large-scale mixing of isotopically heavier felsic igneous rocks with more mantle-like mafic lithologies within the UCC.