The Titanium Stable Isotopic Composition of Chondrites and Earth: Implication for Continental Crust Extraction

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Titanium is a refractory lithophile element, such that its abundance in planetary materials is not modified by core formation or volatile depletion. However, Ti is incompatible during partial melting and fractional crystallization [1], meaning stable isotopic variations of Ti in planetary reservoirs may record processes occurring later in their planetary evolution, such as igneous differentiation and crust extraction [2]. Here we present high-precision double-spike Ti stable isotopic analyses of chondrites and terrestrial samples. Chondrites show a homogeneous titanium stable isotopic composition ($\delta^{49/47}Ti_{IPGP\text{-}Ti}$ = –0.04 ± 0.02‰ (2se) or ± 0.07‰ (2sd), n = 11, i.e., the per mil deviation of the $^{49}Ti/^{47}Ti$ ratio relative to the IPGP-Ti reference material). This chondrite average is ~0.07‰ heavier than the existing estimate for the bulk silicate Earth (BSE) that uses only modern igneous rocks [2]. However, the Ti content of the Earth's primitive mantle (~0.217 wt.%) is higher than that estimated for the contemporary depleted mantle (~0.117 wt.%) [3], implying that a significant fraction of the BSE's Ti budget now resides in the crust. To evaluate whether the difference between chondrites and the current-day BSE estimate is related to continental crust extraction, we analyzed the Ti stable isotopic composition of Archean komatiites. The komatiites have ages from 3.515 to 2.7 Ga, spanning the timeframe for the extraction and stabilization of the continental crust [4]. We find that the oldest komatiites (3.515-3.48 Ga) have chondrite-like $\delta^{49/47}Ti_{IPGP\text{-}Ti}$ (–0.05 ± 0.06‰, 2sd, n = 4), while the younger komatiites (3.28-2.7 Ga) show progressively lower $\delta^{49/47}Ti_{IPGP\text{-}Ti}$ of –0.10 ± 0.01‰ to –0.15 ± 0.02‰. Mass balance calculation, and the fact that the older komatiites have primitive mantle-like chemical signatures suggest that the $\delta^{49/47}Ti$ of the BSE is chondritic.

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