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Confirming the non-chondritic composition of the silicate Earth

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Our recent evaluation of the terrestrial mass balances between the present-day continental crust and the residual MORB+OIB source reservoir, based on Nb/U and ε(Nd) ratios, requires super-chondritic ε(Nd) and Sm/Nd values for the accessible bulk silicate Earth (BSE)[1]. Subsequent publications of high-precision ^{142}Nd data on chondrites [2,3] have reversed earlier assessments that ascribed the non-chondritic terrestrial ε(^{142}Nd) to nucleosynthetic effects[4], and they have revived the earlier interpretation of ^{142}Nd, which also called for a super-chondritic terrestrial Sm/Nd for the accessible BSE[5]. Here we reaffirm our 2022 conclusions using an independent mass balance based on a new evaluation of the "canonical" Ce/Pb and Pr/Pb ratios in MORB and OIB. We show that these ratios are not significantly affected by plagioclase fractionation in global MORB samples and that Pb is intermediate in compatibility between Ce and Pr. The global mass balance can thus be bracketed between Ce/Pb and Pr/Pb. For a chondritic Earth, mass balances based on Ce/Pb, Pr/Pb, and (Nb,Ta)/U ratios for Earth's crust and its mantle residue require the depleted residue to be about twice as large as the one based on ε(Nd). These contradictory mass balances cannot be reconciled for a chondritic Earth, because the residual reservoir includes both MORB and OIB sources, i.e. all accessible mantle sources. However, an early-depleted silicate Earth with a present-day ε(Nd) ≈ +3 would reconcile all of these mass balances. Thus, all three lines of evidence, the mass balances for (Nb,Ta)/U and (Ce, Pr)/Pb, both combined with the ε(^{143}Nd) mass balance, and the terrestrial ^{142}Nd/^{144}Nd ratio, now converge on the same or very similar non-chondritic Earth model(s) requiring an early depletion of incompatible elements by permanent internal sequestration or by collisional erosion[2,6].

[1] Hofmann et al. (2022) G-Cubed 23, https://doi.org/10.1029/2022GC010339.

[2] Frossard et al (2022) Science 377, 1529-1532.

[3] Johnston et al. (2022) Nature 611, 501-506.

[4] Boyet et al. (2018) EPSL 488, 68-78.

[5] Boyet and Carlson (2005) Science 309, 576-581.

[6] O'Neill and Palme (2008) Phil. Trans. R. Soc. A. 366, 4205-4238.