

The NC versus CC origin of Earth's late-stage building materials

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Determining the origin of Earth's building blocks and the timing of their accretion onto Earth is critical for understanding the dynamics of terrestrial planet formation. This information can be obtained from nucleosynthetic isotope anomalies, which can distinguish between materials originating from the inner (non-carbonaceous, NC) and outer (carbonaceous, CC) solar system. Of these, the isotope anomalies in Mo are particularly useful, because owing to its moderately siderophile behavior, most of the Mo present in the bulk silicate Earth (BSE) was delivered during the final 10 to 20% of accretion. Based on a mixed NC-CC heritage of the BSE's Mo it has been concluded that the late stages of Earth's growth contained a relatively large fraction of CC material [1], which was added by a few large CC embryos [2]. However, more recently it has been argued that the BSE and the NC-type IAB iron meteorites have identical Mo isotopic compositions, implying that Earth's late-stage accretion was predominantly NC [3]. To assess as to whether the BSE and IAB irons indeed have identical Mo isotopic compositions, and thereby better constrain the origin of Earth's late-stage building materials, we obtained high-precision Mo isotope data for main-group IAB iron meteorites. We find that in particular for the IAB irons, the measured Mo isotope compositions are affected by non-exponential mass-dependent Mo isotope fractionation in samples with low procedural Mo yields. These fractionations result in spurious Mo isotope variations, which are particularly evident as deficits in ^{92}Mo , ^{94}Mo , and ^{100}Mo [4], signatures unknown from bulk meteorites. We show that these effects result in a shift of the Mo isotopic compositions of IAB irons towards the BSE composition and that samples devoid of non-exponential isotope fractionation exhibit inherent nucleosynthetic Mo isotope anomalies distinct from the BSE. This implies that the BSE has a mixed NC-CC Mo isotopic composition, indicating the late-stage addition of CC material to Earth.

References: [1] Budde et al. (2019) *Nat. Astron.* 3, 736–741. [2] Nimmo et al. (2024), *Earth Planet. Sci. Lett.* 648, 119112. [3] Bermingham et al. (2025), *GCA* 392, 38–51. [4] Budde et al. (2023) *Geochemistry* 83, 126007.