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Searching for Earth's missing non-meteoritic building materials

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Planetary bodies exhibit distinct nucleosynthetic isotope signatures, providing critical insights into the provenance of their building blocks [1]. In multi-elemental isotope space, the terrestrial planets, including Earth and Mars, plot on or close to the trend defined by non-carbonaceous (NC) meteorites, indicating they predominantly accreted from inner solar system materials [2]. The NC isotope trend appears to reflect a heliocentric gradient, where materials closer to the Sun (e.g., enstatite chondrites) show stronger enrichments in the abundances of s-process nuclides. Earth consistently plots at the end of these NC trends, defining an endmember composition and indicating it incorporated s-process-enriched material not sampled among meteorites and which most likely derives from the innermost solar system [2,3]. As such, remnants of this material may have been preserved in primitive chondrites from the NC reservoir. To search for this material we initiated a systematic study focusing on the components of primitive NC chondrites formed at different heliocentric distances and at varying redox conditions. To this end, we separated fine-grained matrix-rich fractions from different NC chondrites and analyzed their nucleosynthetic Ti isotopic compositions. These initial results show that the isotopic compositions of the fine-grained fractions trend away from the compositions of their bulk host meteorite, towards the composition of Earth. Zirconium isotope measurements on the same samples are underway, and will help determine if this fine-grained material is s-process-enriched NC material, or s-process-depleted CC material. In the former case, this material may represent remainders of Earth’s building material that is missing from the meteorite record. Whether this component also exists in the form of distinct planetary bodies remains to be investigated, but is key for understanding Earth’s accretion.

[1] Dauphas (2017) Nature, 541, 521–524. [2] Burkhardt et al. (2021), Sci. Adv. 7, eabj7601. [3] Mezger et al. (2020), Space. Sci, Rev., 216 :27