Increased oxidation during Earth's accretion revealed by correlated isotope signatures

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The oxidation state of the Earth is controlled by the composition of the contributing material during the different phases of Earth's accretion. The presence of water plays a major role as oxidant, where dry, volatile-poor accretion is expected to result in accretion of predominantly reduced solids, whereas wet, volatile-rich accretion provides a more oxidising accretion environment. Therefore, understanding the temporal evolution of the oxidation state throughout Earth's growth provides insights into the timing of delivery of water and other volatile species to the Earth and its early mantle, which are critical to the subsequent evolution of conditions suitable for complex biochemical syntheses.

It has been recently established that changes in the bulk planetary nucleosynthetic isotope signatures of lithophile elements track the progressive admixing of pristine outer Solar System, CI chondrite-like dust to an initially thermally processed inner protoplanetary disk [1]. This observation allows us to determine the mass fraction of CI chondrite-like dust accreted to the terrestrial planets over time. Here, we compare the calcium (Ca) isotope nucleosynthetic signature in planetary mantles formed over distinct timescales with the nucleosynthetic signature of iron (Fe) in the same samples. Given that the partitioning of Fe between the metallic core and the rocky mantle is sensitive to its oxidation state, this approach allows us to track changes in the oxidation state during the accretion of the terrestrial planets. We observe a decoupling between the isotopic signatures of Ca and Fe that occurs during the accretion of the terrestrial planets, where over 90% of the Fe in the Earth's mantle today was added in the later half of the terrestrial planet accretion. This requires a transition from reducing to oxidising conditions during accretion, most likely due to the addition of water. This observation is in agreement with other lines of evidence suggesting that the accretion of the terrestrial water occurred after 60-80% of Earth's accretion [2]. Moreover, our model predicts CI chondrite-like dust is the source of the majority of iron present in the mantle today.

[1] Schiller *et al.*, 2018, *Nature* **505**, 507–510. [2] Peslier *et al.*, 2017, *Space Sci. Rev* **212**, 743–810.