Goldschmidt 2023 Abstract
https://doi.org/10.7185/gold2023.17712

Terrestrial planet formation as recorded by nucleosynthetic heterogeneity of nickel

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According to the pebble accretion theory, rocky planets form by collisional growth of planetesimals followed by a gas-drag assisted accretion of ~mm-sized particles [1]. The final stages were likely to involve a series of giant impacts. Whereas the theory is supported by e.g., observations of protoplanetary disks [2], the relative contribution of either growth mechanism and the role of the impacts are unclear. Collisional growth implies accretion of mostly local material, while pebbles are sourced both locally and from outer parts of the disk which is distinguishable using nucleosynthetic isotope signatures in meteorites. Nickel (Ni) is of particular interest because its core-mantle partitioning is pressure-sensitive making it noticeably less siderophile as accretion progresses [3]. Thus, Ni isotope composition of planetary mantles should primarily reflect that of late accreting material. We present high-precision mass-independent Ni isotope data for ungrouped iron meteorites and inner Solar System achondrites. Nickel was purified by a combination of extraction and ion-exchange chromatography and measured by MC-ICP-MS.

The irons record the primordial nucleosynthetic disk heterogeneity in $\mu^{58}Ni_{62/61}$ which exceeds the range defined by chondrites and provides a framework to interpret the achondrite data. Two angrite meteorites have $\mu^{58}Ni_{62/61}$-signatures that overlap with values typically assigned to carbonaceous material, best understood by admixture of CI-like material after core formation via pebble accretion. Terrestrial and martian mantles have intermediate $\mu^{58}Ni_{62/61}$-compositions that are in apparent conflict with pebble accretion [4]. However, this apparent conflict is resolved when the effects of giant impacts on Earth and Mars are considered, as any contribution of Ni from the impactor core would dominate the resulting isotope signature of the mantle. This finding implies an inner Solar System origin of the Moon-forming impactor and it agrees with a potential explanation of the crustal dichotomy on Mars via a giant impact [5].

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