Goldschmidt 2022 Abstract
https://doi.org/10.46427/gold2022.11119

(2021).

Accretion history of terrestrial planets inferred from their silicon isotope compositions

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The accretion of millimetre-to-centimetre-sized pebbles allows for the growth of massive gas giant cores early enough to for their subsequent gas accretion before the dissipation of the circumstellar disk. In contrast, terrestrial planets are traditionally thought to form by giant collisions between Moon-to-Mars-sized protoplanets over more protracted timescales. However, pebble accretion may also be a plausible mechanism for the formation of the rocky planets in the inner Solar System [1], encouraging further investigation. Nucleosynthetic variability that exists amongst rocky bodies in the Solar System can be used to trace the nature and origin of the precursor material to terrestrial planets. The bulk of existing nucleosynthetic data, however, are based on elements that are minor planetary components, making interpretation of these data ambiguous. Here we focus on the nucleosynthetic composition of silicon (μ^{30}Si), the most abundant refractory planet-building element in primitive and differentiated meteorites to address this issue. Inner Solar System differentiated bodies, including Mars, record deficits in μ^{30}Si whereas enstatite, ordinary and carbonaceous chondrites show μ^{30}Si excesses relative to Earth. This challenges the commonly held view that chondritic parent bodies are the building blocks to Earth and Mars. Instead, the composition of Earth and Mars requires a contribution from material akin to early-formed differentiated asteroids. Moreover, correlation between μ^{30}Si and accretion ages of asteroids implies a secular evolution in the inner disk composition that reflects admixing of a μ^{30}Si-rich outer Solar System component, where the μ^{30}Si-poor composition of Mars requires its formation before μ^{30}Si-rich material could contribute significantly to its growth. Contrastingly, Earth's more enriched μ^{30}Si signature necessitates admixing of of μ^{30}Si-rich outer Solar System material to its precursors, assumed to be akin to the μ^{30}Si-poor achondrites. Numerical simulations show that the formation of Mars and proto-Earth by collisional and pebble accretion must have occurred within 3 Myr of Solar System formation. Thus, Earth's volatiles may have been delivered early by accretion of inward-drifting outer Solar System pebbles to the inner disk.

1. *Johansen, A. et al. (2021), Science Advances 7, 1–14*