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Nickel nucleosynthetic record of magmatic irons and the origin of the Earth

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Nucleosynthetic variability recorded on a bulk meteorite level can be used to fingerprint planetary building blocks. Nickel is of particular interest for this purpose as it has five stable isotopes which allows more in-depth analysis of nucleosynthetic signatures and, moreover, Ni is abundant in a wide variety of meteorite types allowing direct comparison of e.g., chondrites and iron meteorites. We report high-precision mass-independent Ni isotope data for 20 ungrouped iron meteorites together with samples from major groups of magmatic irons. Collectively, these meteorites sampled a large population of planetesimals accreted within 1 Myr of Solar System formation. Thus, they provide knowledge of the initial nucleosynthetic Ni isotope variability of the disk material from which terrestrial planets formed.

Our samples record positively correlated $\mu^{58}Ni_{62/61}$ and $\mu^{60}Ni_{62/61}$ compositions that indicate the presence of measurable initial nucleosynthetic disk heterogeneity, consistent with earlier work [1] but with an improvement in resolution. Critically, our new and extensive dataset shows no evidence for an isotopic discontinuity between non-carbonaceous and carbonaceous iron meteorite parent bodies. The Bulk Silicate Earth (BSE) composition lies above the correlation line defined by iron meteorites in $\mu^{58}Ni_{62/61}$ and $\mu^{60}Ni_{62/61}$ space, similarly to the primitive CI chondrites. Accepting a low initial Solar System $^{60}Fe/^{56}Fe$ ratio [2] we interpret the $\mu^{60}Ni_{62/61}$ variations as nucleosynthetic as opposed to radiogenic. The observation that BSE plots above the correlation line defined by the irons is consistent with incorporation of CI-like material during accretion of the proto-Earth. Thus, our data are in line with models of rapid terrestrial planet formation by pebble accretion [3] as opposed to stochastic collisional growth.

[1] Nanne, Nimmo, Cuzzi & Kleine (2019) *Earth and Planetary Science Letters* 511, 44-54.

[2] Tang & Dauphas (2012) *Earth and Planetary Science Letters* 359-360, 248-263.

[3] Johansen, Ronnet, Bizzarro, Schiller, Lambrechts, Nordlund & Lammer (2021) *Science Advances* 7, eabc0444.