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Iron isotope fractionation during planetesimal core-mantle differentiation

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Core-mantle differentiation is a first-order process that sets the initial stage for geological evolution of a terrestrial planet. This planetary process has been proposed to be recorded in the mantle's iron isotope composition, because iron is a multivalent element ubiquitous in both the silicate mantle and metallic core of a planet Most studies predict a measurable iron isotope fractionation between the core and mantle of small planetesimals, but they disagree on the direction and magnitude of the fractionation Such resolvable fractionation signatures have not been established in meteorite analyses. One potential reason is the limited number of differentiated planetary bodies measured for iron isotope compositions (e.g. Mars, Vesta, and the Angrite parent body).

In recent years, a significant number of ungrouped achondrites have been classified. Aside from those formed through impact melting and differentiation, many of these ungrouped achondrites are igneous in origin and could have sampled the silicate portion of distinct differentiated planetesimals. Previously thought to be almost exclusively from noncarbonaceous chondrite-like bodies in the inner Solar System, some ungrouped achondrites are now also shown to originate from carbonaceous chondrite-like bodies from the outer Solar System through Cr, Ti, and O isotope studies.

In this study, we aim to measure iron isotopic composition of a range of ungrouped achondrites to look for potential signature of iron isotope fractionation due to core-mantle differentiation. To distinguish primary and secondary processes that might have affected the iron isotope composition of these achondrites, efforts were made to measure both bulk meteorites and mineral separates.

We found that most of these meteorites show chondritic iron isotope composition, indicating a lack of core formation signature. One exception is ungrouped achondrite NWA 7325, which we found to have the lightest iron isotope composition of any achondrite measured so far ($\delta^{57}Fe$ = -1.142 ± 0.025‰). Based on leaching experiments and mass balance reconstruction of the igneous signature, we conclude that the iron isotope composition of NWA 7325 reflects that of its parental magma. Our results suggest that the parent body of NWA 7325 might have experienced differentiation processes that are unique among planetary bodies studied thus far.