Tracing volatile accretion dynamics by Mars' Mo isotopic composition

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The discovery that based on their nucleosynthetic isotope signatures, all asteroidal meteorites can be classified into either the *non-carbonaceous* (NC) or the *carbonaceous* (CC) group [1,2], has profoundly changed our understanding of early solar system dynamics and planet formation. Chronological data reveal that the NC and CC reservoirs co-existed and remained spatially separated for several Ma [2,3]. This efficient separation for an extended period of time most likely reflects the early formation of Jupiter [2,3], which not only acted as a barrier against material exchange between the NC and CC reservoirs [4], but also naturally explains the subsequent scattering of CC bodies from the outer into the inner solar system by dynamic excitation during Jupiter's final growth [5].

The arrival and fate of CC material in the inner solar system is likely recorded in the terrestrial planets, which, by contrast to the meteorite parent bodies, formed over an extended period of time and thus potentially sampled both reservoirs. Consistent with this, the Mo isotopic composition of Earth's mantle seems to be intermediate between those of the NC and CC reservoirs, indicating substantial accretion of CC bodies to the growing Earth [6]. However, as Earth accreted over several tens of Ma, the Mo isotopic composition of Earth's mantle provides little information on when CC bodies were scattered into the inner solar system and, hence, when water and other volatiles arrived in the terrestrial planet formation region. Here, we investigate this issue using the Mo isotopic composition of Mars. Since Mars' accretion was most likely completed within ~10 Ma, the presence or absence of a CC isotopic signature in the martian mantle places key constraints on the arrival of CC bodies. Our current data set reveals that –although distinct from Earth's mantle– the Mo isotope composition of martian meteorites also appears to be intermediate between the NC and CC compositions. Take at face value, these data indicate that CC material was scattered into the inner solar system between 4-10 Ma. This would be consistent with the growth history of Jupiter and suggests that volatile rich materials contributed to the growth of the terrestrial planets, including the Earth, throughout most of their accretion history.

[1] Warren (2011) *EPSL, 311*, 93. [2] Budde et al. (2016) *EPSL*, *454*, 293. [3] Kruijer et al. (2017) *PNAS, 114*, 6712. [4] Morbidelli et al. (2016) *Icarus 267*, 368. [5] Raymond & Izidaro (2017) Icarus *297*, 134. [6] Budde et al. (2018) *this meeting*.