

Accretion of the earliest inner solar system planetesimals beyond the water-snowline

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Chronological constraints on meteorites, particularly magmatic iron meteorites, suggest that planetesimals began forming almost at the onset of solar system formation. Although there is a growing consensus that planetesimals associated with carbonaceous (CC) reservoir formed at or beyond the water-snowline, the formation zone of the first non-carbonaceous (NC) planetesimals is debated. Silicate condensation line ($T_{\text{cond}} = 1400$ K) and water-snowline ($T_{\text{cond}} = 170$ K) have been alternately postulated as the potential accretion zone for the first NC planetesimals. However, whether the chemical characteristics of NC iron meteorite parent bodies (IMPBs) are consistent with accretion of water-free or water-bearing materials (corresponding to accretion at the silicate condensation line or water-snowline, respectively) remains elusive because their oxidation states, and associated water contents, have not been constrained quantitatively.

Here we use the Fe/Ni and Fe/Co ratios of magmatic iron meteorites to constrain the oxidation states of NC and CC IMPBs. Since Fe, due to its less siderophile character, can be fractionated relative to Co and Ni at fO_2 relevant for core-mantle differentiation, the depletion of Fe relative to Ni and Co in the cores can directly constrain the amount of oxidized Fe in the mantles. The mass balance of Fe between mantles and cores in tandem with those of Ni and Co can be used to quantify the Fe contents in the mantles of IMPBs. Our results show that the FeO contents of the mantles of NC IMPBs computed from Fe/Ni ratios lie in the range 3-16 wt% and those in CC IMPBs are 10-25 wt%. This shows that NC IMPBs contain substantial amount of oxidized Fe in their mantles and in some cases their FeO contents overlap with their CC counterparts. The first formation of substantial FeO has been linked to environments where the H_2O/H_2 ratio was much greater ($\sim 10^{-1}$) than that of nebular gas ($\sim 10^{-4}$). Interaction of aqueous fluids, generated by the melting of ice during ^{26}Al decay, with metallic Fe provides the ideal setting for the production of oxidized Fe in the mantles of planetesimals. This points towards the accretion of the first NC planetesimals at or beyond the water-snowline.