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Early Solar System Turbulence Constrained by High Oxidation States of the Oldest Non-Carbonaceous Planetesimals

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Planetesimals formed via gravitational collapse of pebble clouds in the early Solar System (SS) constitute the parent bodies of most meteorites investigated today. Over the past two decades, nucleosynthetic isotope anomalies of bulk meteorites have revealed a dichotomy between non-carbonaceous (NC) and carbonaceous (CC) groups, reflective of provenance in the SS protoplanetary disk **[*e.g.*, 1]**. Planetesimals sampling NC and CC isotopic signatures are conventionally thought to originate from the “dry” inner disk, and volatile-rich outer disk, respectively, with their segregation enforced by Jupiter’s formation at the water-ice sublimation front. This simple framework, however appealing, is challenged by emerging evidence that the oldest NC planetesimals (*i.e.,* the iron meteorites parent bodies; IMPBs) were characterized by far higher oxidation states than previously imagined, suggesting abundant liquid water in their interiors **[2]**. Building on the work of Zhang et al. **[3]**, we develop a model for a degassing icy planetesimal, mapping the conditions for liquid water production therein. Our work culminates in a threshold characteristic size for pebbles composing the said planetesimal, under which water-ice melting occurs. Adopting a model for a disk evolving under both turbulence and magnetohydrodynamic disk winds **[4, 5]**, we self-consistently translate the threshold pebble size to lower limits on early SS turbulence. We find that for NC IMPBs to have been “wet,” their constituent pebbles must have been less than a few centimeters, corresponding to typical values for the Shakura-Sunyaev turbulence parameter in excess of 10^{-3}. These findings are discussed in the context of empirical constraints on disk turbulence (*e.g.,* ALMA observations) **[6]**, and SS planet formation. Regarding the latter, our findings argue against the dominance of pebble accretion in building our rocky planets **[5]**, in accord with geochemical inferences.

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