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Sub-solar Al/Si and Mg/Si ratios of the enstatite chondrites reveal planetesimal formation during early condensation in the protoplanetary disk

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Abstract

The Al/Si and Mg/Si ratios in enstatite/ordinary chondrites are smaller than the solar (i.e. CI-chondritic) values. Interestingly, for the Earth it is the opposite: these ratios are larger than in CI meteorites. This excludes the possibility that the Earth is predominantly made of enstatite chondrites, despite the close similarities in isotope compositions. We show that the accretion of a first generation of planetesimals during the condensation sequence of refractory elements implies the subsequent formation of residual condensates with strongly sub-CI Al/Si and Mg/Si ratios. The mixing of residual condensates with different amounts of material with CI-like refractory element ratios explains the Al/Si and Mg/Si values of enstatite and ordinary chondrites. The combination of first-formed planetesimals from incompletely condensed material, possessing strongly fractionated Al/Si and Mg/Si ratios, with enstatite chondrites or CI-like material can then explain the values of these ratios in the Earth. To match quantitatively the observed ratios, we find that the first-planetesimals should have accreted when the disk temperature was 1,400K-1,425K at an assumed disk's pressure of 1.e-3 bar. We discuss how this model relates to our current understanding of disk evolution, grain dynamics, and planetesimal formation. We also show that this new view of the genetic relationship between the Earth and enstatite chondrites resolves the conundrum of their differences in element composition yet their similarities in isotope compositions. The slight differences in some isotope ratios between Earth and enstatite chondrites can also be understood in the framework of this model. We also extend the discussion to the enrichment of enstatite and ordinary chondrites in moderate volatile elements (e.g. Na) compared to non-CI carbonaceous chondrites.