MO-W ISOTOPIC EVIDENCE AGAINST CHONDRULE-MATRIX COMPLEMENTARITY

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Introduction: Understanding whether a genetic relationship exists [1-3] or not [4-5] between the high-temperature components of chondrites (chondrules, refractory inclusions and metal, here referred to as “chondrules”) and their embedding matrix is critical to our vision of the protoplanetary disk (PPD). The existence of such a relationship would indicate accretion to have taken place shortly after the formation of all these components, and thus make their transport within the disk unlikely. [1-3] and references therein argue that while carbonaceous chondrites (CCs) exhibit “chondritic compositions”, i.e. CI chondritic ratios of the major elements Si, Mg (Fe…), each group has a specific matrix composition, with higher Si/Mg and Fe/Mg ratios than those of the bulk. These authors contend that in each CC group, the composition and proportion of chondrules are exactly suited to those of their embedding matrix to reach a chondritic bulk and make the case that, as Mg and Si distribution cannot result from parent body processes, chondrules and matrix must have been formed simultaneously from a single reservoir of CI composition. This hypothesis recently received apparent support from the isotopic work of [6,7]. Three nucleosynthetic processes, the s-process, the r-process and the p-process, produce W and Mo with distinctive isotopic patterns [6,7]. [6,7] found different nucleosynthetic isotopic signatures in W and Mo in chondrules (with an s-process deficit) and matrix (with an s-process excess) in the Allende CV3. They point out that such anomalies must result from the uneven distribution between chondrules and matrices of a presolar carrier enriched in s-process Mo and W nuclides creating an isotopic “complementarity”. They argue that this uneven distribution of nucleosynthetic anomalies was established during chondrule formation, and speculate that it may be related to metal-silicate fractionation [6,7]. However, [6,7] offer no convincing mechanism to explain how chondrule formation might have generated such an uneven distribution of the presolar carrier(s). Size or type sorting between matrix and chondrules, or incomplet melting followed by physical separation of the unmelted crystals are invoked, which is not predicted in any actual chondrule formation mechanism proposed so far.

Discussion : In fact, no isotopic differences between chondrules and matrix should be observed if chondrules and matrix were formed from the “same” reservoir of material as argued by [1,3], who attribute the “complementary" chemical differences between chondrules and matrix to evaporative fractionation during chondrule formation followed by recondensation on the matrix. The arguments of [1-3] have thus been convincingly refuted by the isotopic work of [6,7] that demonstrated that chondrules do not originate by chemical fractionation from the same isotopically defined reservoir of material as matrix, but that these two components originated from entirely different reservoirs with distinct nucleosynthetic origins. Unfortunately, [6,7] do not draw this interpretation of their own data, but prefer to follow [1-3] in arguing that when two different reservoirs are added together the resulting mix is always intermediate between the two. What this line of reasoning ignores is that there is no “chondritic” composition for Mo isotopes [8]. [7] reported two measurements of bulk Allende with significantly different Mo isotope compositions that plotted between the Mo anomalies of chondrule and matrix fractions, but which differ even more significantly from the Mo isotopic composition of bulk Allende reported by [8], that has a larger s-process Mo isotope deficit than the Allende chondrule fraction [7]. [7] state that these results demonstrate “ significant Mo isotope heterogeneity among bulk samples of Allende, even for samples prepared from powders of ∼40 g and ∼100 g material ” and suggest that this must result from the uneven distribution of CAIs with highly anomalous Mo isotope compositions. These results show that the Mo isotopic composition of bulk Allende is not well constrained, that it is unlikely to be close to that of CIs as the available measurements are skewed towards s-process deficits. In addition, anomalous CAIs would need to be taken into account into the bulk Mo isotope budget of the rock in order to discuss isotopic complementarity.

Conclusion : The differences in nucleosynthetic Mo and W isotopic signatures between chondrules and matrices appear unlikely to have been established as the result of the chondrule forming process operating on material derived from the same reservoir of an initially solar composition after the presolar carriers were physically separated. Isotopic complementarity thus argues in favor of chondrules and matrices being derived from different isotopic reservoirs.

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