THE NON-COMPLEMENTARY COMPOSITIONS OF CHONDRULES AND MATRICES IN CO, CM AND CR CHONDRITES.

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Introduction: In a comprehensive study of carbonaceous chondrites (CCs), we have determined the abundances and average compositions of their main components [1]. The major components - chondrules and matrix - have been suggested to have co-evolved from the same reservoir, based on seemingly complementary absolute element ratios like Si/Mg, Fe/Mg, Ti/Al and Ca/Al [2 and ref. therein]. Other studies, however, have found that chondrules and matrix are not genetically related [e.g., 3-7], with matrix having a ~CI-like composition and chondrules being largely responsible for the moderately volatile element fractionations in bulk CCs.

Method: Combining point-counting with electron microprobe analyses, we have investigated 12 COs, CMs and CRs (>23,000 data points; for details on the methodical approach see [1]). We preferentially selected the most primitive samples but also examined the well-studied falls Kainsaz (CO), Paris (CM) and Renazzo (CR) in order to verify our method. We were able to reproduce all major and many minor elemental concentrations reported in the literature [7, 8] to better than 10 %. The elements Mg, Si, Al, Ca, Fe and Ti are the ones most commonly cited in the context of chondrule-matrix-complementarity. However, Fe can be easily affected by chondrule metal-silicate fractionation, redistribution in the parent body and weathering, and our Ti data for matrix are likely compromised by an analytical artifact. Hence, we focused on Mg, Al, Si and Ca – which we can determine very accurately in all three CC groups.

Results: For some thin sections, our Al and Ca data reveal alteration (Allan Hills [ALH] 77307, Paris, Renazzo) and weathering (Acfer 094) effects. Consequently, these samples are ill suited to test models addressing the evolution of chondrules and matrix. For all other samples, the Si- and CI-normalized abundances of Al, Mg and Ca in the bulk meteorites are similar to the literature data [7]. All matrices are somewhat depleted in Mg. The CM matrices also display clear Ca deficits. Concomitantly, the CO and CM matrices are enriched in Al (and Ca: Dominion Range [DOM] 08006). Unlike their matrices, the CO and CR chondrules exhibit CI-like compositions. The Mg/Si/CI ratios in the CM chondrules are slightly elevated but the relative abundances of Al and Ca are lowered.

Discussion: The complementarity hypothesis implies that, in a closed system, the relative distances of the chondrules and matrix compositions from CI are inversely proportional to their relative mass fractions (the lever rule). Our Mg, Si, Al and Ca data, however, are inconsistent with this correlation. In addition, the CO and CR chondrule compositions are CI-like and the bulk CO and CM compositions are also governed by their refractory inclusions (RIs) – an observation that is not accounted for by the complementarity hypothesis.

Alternatively, chondrules, matrix and RIs could have formed in different places and/or at different times. [7] proposed a model that, to first order, explains the bulk compositions of the CC groups as variable mixes of the same four components (RIs, chondrules, matrix and water). The signatures of Mg, Al and Ca – normalized to Si and CI – in CC chondrules and matrices observed in this study can be explained on the basis of this four-component model and factoring in the loss or addition of forsterite and refractory material (except the Ca deficit in CM matrix). For example, the deviation from CI-like relative abundances of the CO and CR matrix compositions can plausibly be explained if 10-15 wt.% of forsterite were lost from the matrix dust prior to or during accretion. The evidence for the disk-wide transport and exchange of forsterite and RIs has been described by [9-11].

The Ca deficiency observed in CM matrix might have been already established upon accretion. This scenario, however, would require the pre-accretionary fractionation of Al and Ca – two refractory elements that otherwise behave in very similar cosmo/geochemical manners. Alternatively, we suggest that the CM matrix is Ca-deficient due to Ca mobilization (on the thin section scale) during alteration and weathering. Yet, how this transport can be reconciled with signs of only incipient aqueous alteration and modest weathering, and why it affected the CMs but not the COs or CRs, remains to be explored.

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