

THE CHONDRITIC ASSEMBLAGE.

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Introduction: Chondritic meteorites comprise components formed or processed at high temperature embedded in a volatile-rich fine-grained matrix, the origin of which is still debated. Understanding the links between matrix and the other chondritic components is critical to our vision of the protoplanetary disk (PPD). They may have formed independently [1], whereas a genetic relationship between them would indicate accretion to have taken place shortly after they formed and thus make their transport within the disk unlikely. The discovery of chemical relations between chondrules and matrix within given chondrites has led several authors [2-4] to suggest these components formed simultaneously from the same reservoirs, the compositions of which would be chondritic (CI) in terms of major elements such as Si and Mg [2,4] and more or less depleted in volatile elements depending on the chondrite group [3]. Because obtaining a reliable bulk composition of chondrules within a chondrite is difficult, many arguments developed by these authors are based on comparing matrix composition to that of the bulk rock.

Complementarity in volatile elements. [3] compared bulk and matrix compositions in carbonaceous chondrites (CCs) and showed them to mimic one another: if the bulk is highly depleted in volatiles (CVs), so is the matrix, but to a lesser extent. In contrast, when the bulk is less depleted (CMs), then matrix is even less so. [3] concluded this pattern indicated that these rock components had formed simultaneously from the same reservoir.

Complementarity in major elements. [4] and subsequent work by this group argue that all CCs exhibit CI chondritic ratios of the major elements Si, Mg (Fe...), but that each group has a specific matrix composition, with a lower Mg/Si ratio than that of the bulk. This would imply 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. These authors make the case that Mg and Si distribution cannot result from parent body processes, and hence that chondrules and matrix must have been formed simultaneously from a single reservoir of CI composition.

Results and discussion:

In [5], however, we showed chemical redistribution between chondrules and matrix to have taken place in the course of parent body alteration in the Paris CM, which would explain the similarity in volatile depletion patterns for matrix and bulk in CCs. Matrix, originally CI in composition, would have lost some of its volatiles to the chondrules, resulting in a small volatile depletion in the cases where the matrix comprises most of the rock (CMs) but much more pronounced in the cases where matrix is significantly less abundant than chondrules (CVs and COs).

Here, we discuss the case of the major elements based on data from [4] and subsequent work by these authors. (a) A Ti and CI normalized concentration diagram as a function CC group (Figure 3 of [6]) shows that only CI chondrites are actually chondritic. All other chondrites are fractionated in a systematic way that is volatility-related. Si and Mg, which have similar condensation T, are not fractionated with respect to one another but they are with respect to every other element and to a varying extent in all CC groups. (b) Chondrules from the different CC groups have chemical compositions that are indistinguishable, except possibly for their 10% lower Mg/Si in CRs. (c) Bulk chemical chondritic compositions cannot be reconstructed from the chemical compositions and modal abundances of their chondrules and matrices, whereas a more satisfactory match is obtained by adding the observed amount of matrix of CI composition to average CC chondrules along with metal and refractory inclusions. (d) Matrix analyses are performed in situ with the EMP, a method that may be precise but not necessarily accurate because the beam has to analyze a mixture comprising phases of varying density and pores. In fact, matrix analyses performed by LA-ICP-MS [3] yield chondritic Mg/Si ratios, whereas Orgueil analyzed by defocussed beam EMP [7, 8, and this work] is not chondritic.

Conclusion: Complementarity between the high-T and the low-T fractions of the chondritic assemblage would have important implications for our understanding of the PPD, but the chemical data available at present for bulk CCs, matrices and chondrules do not appear to support it. New and more accurate analyses are needed and will soon be available for the matrices of primitive chondrites [9]. Our results are consistent with the two-component model of [1], which suggests that chemical variations in CCs may be simply explained by the mixing of a high T component (including metal and CAIs) with varying amounts of a CI matrix. A time interval and transport taking place between the formation of chondrules and their accretion are thus not ruled out.

References: [1] Anders, E. (1964) *Space Sci. Rev.* 3, 583-714. [2] Wood, J. (1985) *Protostars and Planets II*, p. 687. [3] Bland P. et al. 2005 *PNAS* 102, 13755–13760. [4] Hezel D. and Palme H. 2010 *EPSL* 294, 85-93. [5] Zanda B. et al. (2012) *LPS XLIII*, 2413.pdf. [6] Palme H. (2001) *Phil. Trans. A* 359, 2061-2075. [7] McSween, H. Y., Jr. and Richardson, S. M. (1977) *Geochim. Cosmochim. Acta* 41, 1145-1161. [8] Zolensky, M. et al. (1993) *Geochim. Cosmochim. Acta* 57, 3123-3148. [9] Zanetta, P.-M. et al. (2017), *this meeting*.