CHEMICAL COMPOSITION OF MATRIX AND CHONDRULES IN CARBONACEOUS CHONDRITES: IMPLICATIONS FOR DISK TRANSPORT. B. Zanda[1,2] , M. Humayun[3], and R. H. Hewins[1,2], [1]MNHN & CNRS, 61 rue Buffon, 75005 Paris, France (zanda@mnhn.fr); [2]Dept. of Earth & Planetary Sciences, Rutgers University, 610 Taylor Rd., Piscataway, NJ, (hewins@rci.rutgers.edu); [3]Dept. of Earth, Ocean & Atmospheric Science and National High Magnetic Field Laboratory, Florida State University, Tallahassee, FL 32310, USA (humayun@magnet.fsu.edu).

Introduction: Unequilibrated carbonaceous chondrites contain a high temperature fraction (refractory inclusions, chondrules and metal grains) set in a low temperature interstitial fine-grained matrix. Matrix is enriched in volatile elements compared to bulk rocks [e.g., 1, 2] and the site of presolar grains and organics. The actual chemical composition of matrix, and its relationship with the high T fraction, have remained controversial for over 40 years. Anders [3] suggested that volatile-depleted/refractory-enriched bulk compositions of chondrites could be explained by a two-component model, in which a volatile-rich, CI-like, component accreted with volatile-depleted chondrules (formed from the same type of material but having experienced volatility-dependent evaporative loss during melting). In contrast, Wasson and Chou [4] proposed a more gradual origin for the volatile depletion of chondrites: the incomplete condensation model, in which a gas of solar composition dissipating during condensation generates the precursors of the high T fraction. In the latter case, matrix is logically a nebular product, resulting from complete condensation, while in the former case, it is likely to be well mixed nebular dust of unspecified origin, possibly presolar.

Lately, several authors [e.g., 5, 1], have proposed that there exists a chemical complementarity between the high T fraction and the matrix in each given chondrite, implying that both components must have formed from a common nebular reservoir. Such complementarity would rule out models such as the X-wind model for the formation and transport of CAI and chondrules in the protoplanetary disk. At least three factors contribute to making it difficult to distinguish between these hypotheses: (1) matrix cannot be readily isolated, and reliable in situ analyses have not been available, especially for the volatile trace elements; (2) the high T fraction is very diverse and divided, hence even more difficult to analyze; (3) matrix and the high T fraction are likely to have reacted together during parent-body alteration and/or metamorphism. We analyzed petrographically well-characterized matrix and chondrules in several primitive carbonaceous chondrites (including Acfer 094, Renazzo and Paris) by LA-ICP-MS, to test the ideas discussed above.

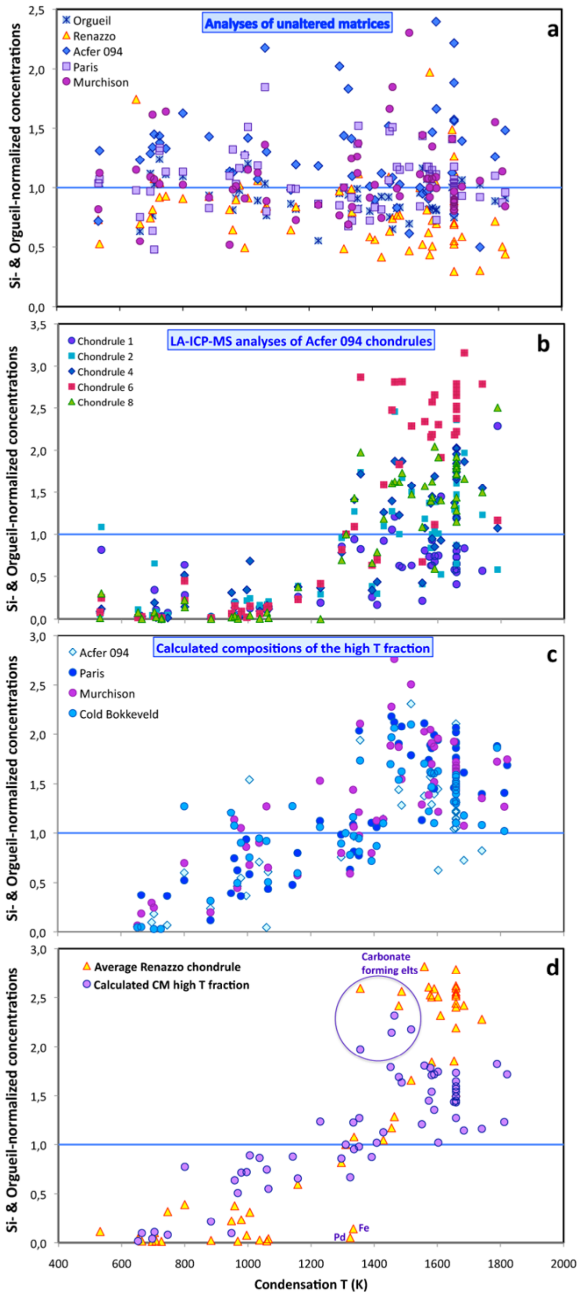
Method: Bulk chondrite compositions were measured by an in-situ rastering of ~0.25 cm^2 squares. In addition, carefully selected unaltered looking matrix patches were analyzed, as well as as several “typical” chondrules. Last, the “bulk” composition of the high T fraction itself, was evaluated for each chondrite, by subtracting the contribution of the matrix fraction from the composition of the bulk rock. After [6], we used the bulk concentrations of the most volatile species (postulated to be present exclusively within the matrix) to evaluate the amount of matrix within the rock.

Results: All the results shown in Fig. 1 are Si- and Orgueil normalized, using the abundances from [7].

Matrix composition. Fig. 1a shows our own analysis of Orgueil along with unaltered matrix patches from Renazzo (CR2), Acfer 094 (CM3.0), Murchison (CM2) and Paris (CM2). All the patterns are flat and chondritic – Renazzo appears somewhat low, presumably due to an excess of the reference element Si. Dispersion is greater in Acfer 094 than for the other chondrites: this is due to the small size of the area available for bulk analysis in our sample.

Chondrule compositions. Fig.1b shows the compositions measured in 5 chondrules in Acfer 094. These compositions are typically refractory-enriched and highly depleted in volatile elements. They do not span a very large range, but chondrule 6 appears enriched in refractory elements by ~ 20% compared to the others.

Composition of the high T fraction. By considering that all elements with a 50% condensation T below 750 K are located within the matrix, and averaging their depletion in the bulk chondrites compared to CI, we were able to estimate the fraction of matrix contributing to the bulk compositions: 57% in Acfer 094; 61% in Murchison; 55% in Paris and 51% in Cold Bokkeveld, in agreement with [6] for Murchison and Cold Bokkeveld. The compositions of the corresponding high T fraction in the 4 chondrites, calculated by subtracting the corresponding amount of CI material [7] from the bulk compositions, are shown in Fig. 1c. These are virtually undistinguishable, and well within the range of the analyses of chondrules from Acfer 094 shown in Fig. 1c. These calculated compositions are averaged to obtain a more precise the composition of the high T fraction in CM chondrites, shown in Fig. 1d.



Composition of chondrules in Renazzo. The bulk composition of Renazzo has not been measured yet, so that the composition of the high T fraction cannot be estimated. Fig 4d displays the "average chondrule" we measured in Renazzo (based on 4 measurements). It appears to exhibit a slight excess in refractory elements, similar to that measured in chondrule 6 of Acfer 094. This pattern is present in 3 of the 4 chondrules averaged, but it is still too early to say whether there is a significant difference in the composition of the high T fractions in CR2 Renazzo and in CM chondrites.

Discussion: (1) - These new results confirm our previous findings that the pre-parent body composition of carbonaceous chondrite matrices was CI chondritic in terms of volatile elements [8]. In the case of CM chondrites, matrix compositions evolved due to fluid-driven exchange with the high T fraction in the course of parent-body alteration [8].

(2) Our findings also imply that the amount of fine-grained material in CM chondrites does not accurately reflect the amount of "true" matrix, i.e. of fine-gained CI-like nebular dust. 61% of true matrix in Murchison and 55% in Paris have to be compared with our own modal measurements of 71% and 66% respectively, made on large areas, and on the same section for Murchison [9]. The difference is even more striking for-Cold Bokkeveld, shown to contain 74% "matrix" [10], but for which we find only 51% based on the volatile element content of the bulk rock. This suggests that some of the fine-grained material is either volatile depleted accretionary rims, or the product of the alteration of the high T component, either of which may explain the volatile depleted "matrix" analyzed by [1].

(3) The bulk compositions of CM chondrites are easily explained by the mixing of a high T fraction with variable amounts of a CI matrix. Although comprising individual objects as different as CAIs and chondrules, the high T fraction has the same bulk chemical composition in all the CMs we analyzed so far. The presence of CI matrix is inconsistent with the idea of chondrule-matrix complementarity, as advocated by and [1], and suggests transport from the reservoir(s) in which CAIs and chondrules were formed to a quiescent part of the disk.

Conclusions: Our data are consistent with the two-component model of Anders [3] and allow chondrules and matrix to be formed independently in the protoplanetary disk, which a pre-accretion complementarity between matrix and chondrules would rule out. It is thus conceivable that high T components formed near the Sun were transported over large distances and mixed in with the matrix in colder regions of the disk as suggested by [11].

References:

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