

**VOLATILE ELEMENT DISTRIBUTION IN MATRIX AND CHONDRULES OF CARBONACEOUS AND ORDINARY CHONDRITES.** B. Zanda<sup>1,2</sup>, P. A. Bland<sup>3</sup>, C. Le Guillou<sup>4</sup> and R. H. Hewins<sup>1,2</sup>, <sup>1</sup>Muséum National d'Histoire Naturelle & CNRS, 61 rue Buffon, 75005 Paris, France ([zanda@mnhn.fr](mailto:zanda@mnhn.fr)); <sup>2</sup>Dept. of Earth and Planetary Sciences, Rutgers University, 610 Taylor Rd., Piscataway, NJ, ([hewins@rci.rutgers.edu](mailto:hewins@rci.rutgers.edu)); <sup>3</sup>Impacts and Astromaterials Research Centre (IARC), Dept of Earth Science and Engineering, Imperial College London, South Kensington Campus, London SW7 2AZ, UK ([p.a.bland@imperial.ac.uk](mailto:p.a.bland@imperial.ac.uk)); <sup>4</sup>Laboratoire de Géologie de l'ENS, 24, rue Lhomond, 75231 Paris, France ([cleguill@clipper.ens.fr](mailto:cleguill@clipper.ens.fr)).

**Introduction:** The origin of chemically and isotopically fractionated chondrite groups is a long standing debate. Volatile elements reside in the low T matrix but may also be present in some chondrules, the latter being volatile depleted, but to varying extents. In OCs, type II chondrules appear less depleted in moderately volatile elements than type Is but equally depleted in highly volatile elements [1]. These depletions may result from evaporation during chondrule formation [1] but precursor effects and close-system behavior have also been advocated. Among the key questions are (i) whether the volatile fractionation is all carried by varying abundance (and possibly composition) of the matrix or whether the high T fraction also contributes due to precursor effects or varying degrees of evaporation and (ii) whether a complementarity exists between matrix and chondrule compositions in a given chondrite as advocated by [2].

**Method and results:** We use the data of [2-5 + references therein] to compare the bulk compositions of OCs and CCs with their modal abundance of matrix. Results are shown in Fig. 1. All the chondrites used to establish the regressions have petrographic types  $\leq 3.4$  (after [6-7] for CCs). More metamorphosed chondrites are also displayed in Fig 1a&b. To clarify the picture, the linear correlations were “forced” through the origin in all cases (except Fig 1e), which did not affect the determination coefficients  $R^2$  in any significant way.

**Discussion:** When only the least metamorphosed CCs are considered, the regressions for H<sub>2</sub>O, C, N and for presolar diamonds all pass very close to the origin, indicating that these species were present exclusively in the matrix at the time of accretion and that matrix had a uniform composition in these species.

*Effect of metamorphism.* In [8], we found that C & H<sub>2</sub>O concentrations in CCs correlated with the amount of matrix but did not intercept the X axis at 0, implying that a fraction of the matrix did not contain these species. The picture changes considerably once chondrites with petrographic types  $>3.4$  are removed from the regressions. (These are displayed as \* in Fig. 1a&b). The regression line for primitive CCs lies above the metamorphosed CC points and goes towards the origin through the primitive OC data points. We infer that objects with petrographic types  $>3.4$  lost H<sub>2</sub>O and C. The points for the 2 CVs (Efremovka and

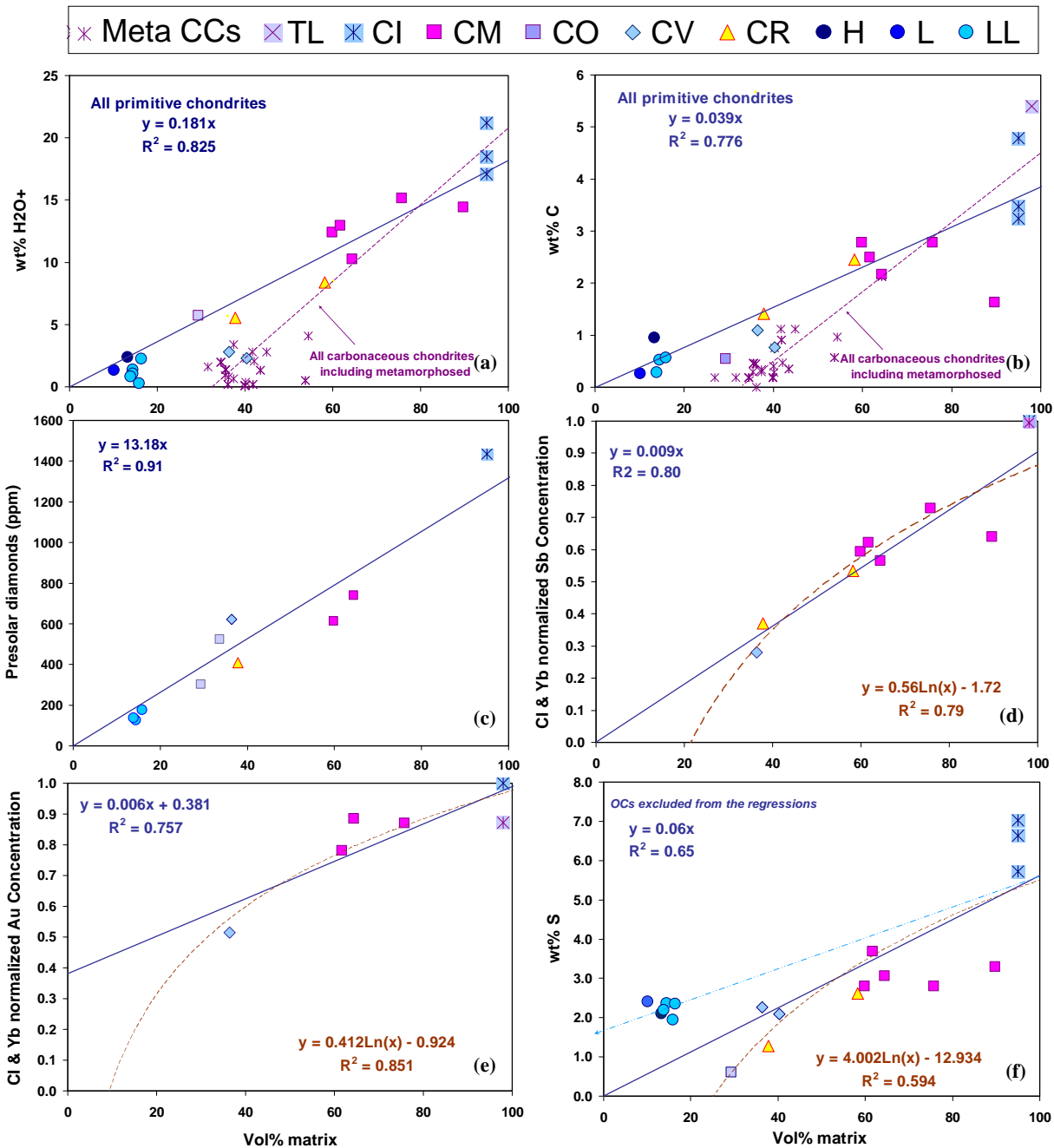
Vigarano, both 3.1-3.4 [6] ) lie slightly below the regression line, suggesting that even these may have lost some water and possibly C due to a mild metamorphism.

*Highly volatile elements in CCs.* Fig. 1d shows regression trends for Sb (K and more volatile elements like Tl, Bi Zn, Ge & Ga follow similar patterns). The linear trend goes through the origin, implying as for H<sub>2</sub>O & C that these elements were accreted within a matrix of constant composition. However, the lack of points corresponding to less than 30 vol% matrix (no such CCs, scant data for primitive OCs, which appear above the trends as in the case of S discussed below) make it impossible to differentiate between a linear trend and a logarithmic one corresponding to an increasing depletion of the matrix as it gets less abundant (and the bulk chondrite gets more fractionated).

*Moderately volatile elements in CCs and the case for S.* The linear regression trends for moderately volatile elements (Au, Cu) in CCs intercept the Y-axis above zero, which indicates that their high T fraction also contains these elements, if CC matrix indeed has a constant composition. S is the only volatile element for which we have extensive data for primitive OCs as well as CCs. It is more volatile than K and the linear regression for CCs goes through the origin. With ~2 wt%S, OCs fall well above this trend because they contain FeS within and around their chondrules.

*Composition of the matrix and matrix-chondrule complementarity.* The linear trends for the most volatile elements (H<sub>2</sub>O, C and N) and the presolar diamonds in CC and OC groups suggest a uniform composition of the matrix for these species. The data for highly to moderately volatile elements in CCs may be interpreted similarly but are also consistent with a logarithmic trend implying a smoothly increasing depletion mimicking that of the bulk chondrite and hence chondrule-matrix complementarity [2]. An alternate explanation that may reconcile linear trends with the matrix composition variations described by [2] may be that volatile elements not lost during a mild metamorphism were redistributed from the matrix to the chondrules as is observed for S in type I chondrules in OCs.

**Conclusion:** [4] showed that oxygen isotope mass fractionation ( $\Delta^{18}\text{O}$ ) throughout chondrite groups re-



**Figure 1:** H<sub>2</sub>O, C, presolar diamond, Sb, Au and S concentrations as a function of matrix modal abundance in primitive ordinary and carbonaceous chondrites. Dashed curve – logarithmic fit.

flect varying matrix proportions. Similarly, presolar diamond, water, C and N concentration variations in OC and CC groups are due only to varying abundances of a common matrix as suggested by [5]. Whether this also applies to highly and moderately volatile element concentrations within CCs is debatable. On the other hand, variations in volatile element concentrations between CCs and OCs, also reflect variations in the high T component compositions.

**References:** [1] Gordon S. H. et al. (2008) *LPS XXXIX*, Abstract #2034. [2] Bland et al. (2005) *PNAS* 102, 13755–13760. [3] Jarosewich E. (1990) *Meteoritics* 25, 323–337. [4] Zanda B. et al. (2006) *EPSL* 248, 650-660. [5] Huss G. et al. (2003) *GCA* 67, 4823-4848. [6] Bonal et al. (2006) *GCA* 70, 1849-1863. [7] Bonal et al. (2007) *GCA* 71, 1605-1623. [8] Zanda B. et al. (2008) *LPS XXXIX*, Abstract #1532.