

**A MEMORY OF ANCIENT ICES PRESERVED IN CARBONACEOUS CHONDRITE MATRICES.** B. Zanda<sup>1,2</sup>, R. H. Hewins<sup>1,2</sup> and F. Robert<sup>1</sup>, <sup>1</sup>Muséum National d'Histoire Naturelle & CNRS, 61 rue Buffon, 75005 Paris, France (zanda@mnhn.fr); <sup>2</sup>Dept. of Earth and Planetary Sciences, Rutgers University, 610 Taylor Rd., Piscataway, NJ, (hewins@rci.rutgers.edu)..

**Introduction:** Variations in C, N and H<sub>2</sub>O abundances in carbonaceous chondrites may stem from post-accretionary asteroidal alteration [e.g. 1]. However, the positive trends observed by [1] between C and N abundances (reproduced top of Fig. 1), as well as between  $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$ , suggest that these elements reside in a common host or, rather, resided in a common host at the time (possibly accretion) when bulk chemical patterns were established. Based on its atomic ratio C/N = 22, the common host appears closely related to the insoluble organic matter (IOM) of carbonaceous chondrites that contains most of the C and N present in these objects. In the present abstract we look at correlations between bulk C and water abundances (derived from wet chemistry) as well as  $\Delta^{18}\text{O}$  and discuss their implications.

**Results and discussion:** Figure 1 shows that bulk H<sub>2</sub>O abundance correlates with C and N, suggesting that water was also associated with the same host at the time of chemical fractionation. This phase appears to have been most abundant in Tagish Lake and the CI chondrites, abundant in CMs and less so in the more metamorphosed COs, CVs and CKs. As water reacted with the silicate phases during alteration, whereas C (and N) remained within the IOM, they should have decoupled during alteration. This implies that the chemical fractionation was established prior to alteration which must, as a consequence, have occurred in a closed system. A similar conclusion was reached by Clayton and Mayeda [4] based on the lack of fractionation of the soluble elements in CI chondrites compared to the Sun.

By balancing the hydration reaction olivine + pyroxene + water yields serpentine, these authors [4] estimated as 0.29 the minimum water to rock ratio ( $\chi$ ) required for complete hydration (where  $\chi$ =moles of O in water / moles of O in rock). Based on the bulk chemistry of carbonaceous chondrites [3], we calculate that their actual water to rock ratio ranges in CMs from 0.3 (Murchison) to 0.5 (Nawapali) and up to 0.7-0.8 in CIs. This means that the water necessary to completely hydrate these rocks was available during their parent-body alteration. The hydration reaction, however, never went to completion in them, which is hardly surprising. Alteration of terrestrial rocks is known to require orders of magnitude higher water to rock ratios, resulting from a constantly circulating body of

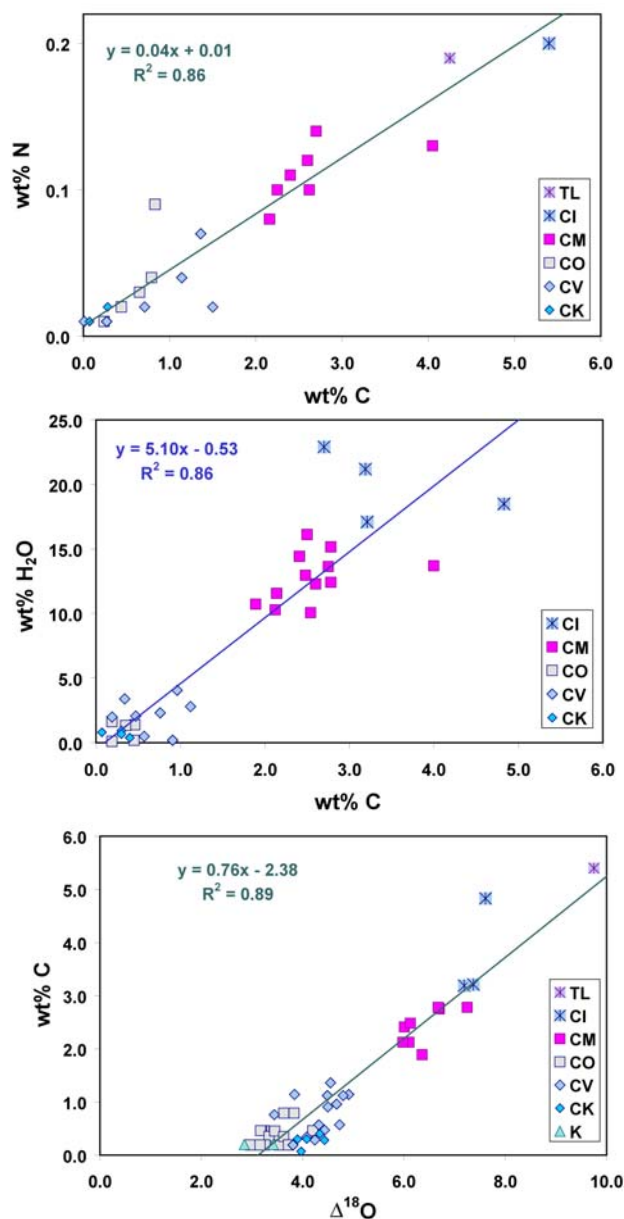


Figure 1. Bulk abundances of C, N and H<sub>2</sub>O in carbonaceous chondrites correlate with  $\Delta^{18}\text{O}$ , itself a proxy for matrix abundance [2]. (Data from Jarosewich [3], Pearson et al. [1] and Clayton and Mayeda [4].)

water in an open system. By analogy, most asteroidal alteration models also postulate fluid flow (e.g. [5]). It is indeed clear that some amount of water circulation did happen on parent bodies as testified by the pres-

ence of large carbonate veins and the local redistribution of some of the soluble elements such as Ca, Zn and Si [6]. Bulk chemical composition of carbonaceous chondrites suggests, however, that this circulation remained limited, most of the alteration taking place locally so that the water content of the rocks was globally preserved. This interpretation is consistent with the findings of Palmer et al. [7] who showed that Murray (CM) had experienced vast variations in the level of aqueous alteration over short distances suggesting ice entrained in the parent body as a possible source of aqueous alteration.

The effectiveness of the hydration of carbonaceous chondrite matrices despite the absence of a circulating fluid may result from the chemical disequilibrium and especially the physical properties of this material prior to alteration. Studies of the least altered type 3.0 chondrites suggest very fine-grained (typically 200-300 nm) Mg-rich olivine and pyroxenes embedded in an abundant amorphous Si, Mg, Fe-rich material [8]. The amorphous material is particularly susceptible to alteration, transforming into phyllosilicates [8,9] which appear to have replaced it totally in the matrix of more altered chondrites such as Semarkona (LL3.0) in which smectite is now the dominant phase [6].

On the other hand, the idea that liquid water in a parent body could not have remained static long enough to induce alteration because it should have been evaporating to space from its surface favors of an open system. Comets, however, are known to have formed hydrocarbon and silicate crusts which preserve ice in their interiors. It is conceivable that a similar mechanism occurred on CI and CM parent bodies and blocked the transport of liquid water to the surface.

$\Delta^{18}\text{O}$  was shown by [2] to be a proxy for the abundance of matrix. It is thus expected that  $\text{H}_2\text{O}$ , C and N concentrations should correlate with  $\Delta^{18}\text{O}$  as shown on Fig. 1. It is surprising, however, that the abundances of these species become zero when  $\Delta^{18}\text{O} \approx 3\%$ , corresponding to 30-40% matrix in the rock (for example, Karoonda contains 0.07 wt% C, 0.01 wt% N and 0.8 wt%  $\text{H}_2\text{O}$  yet 36 % matrix). A fraction of the matrix is consequently free of water and organics. The 3% intercept of the correlation implies that this “dry” matrix is mixed in constant proportions with chondrules/CAI, and then diluted by the “wet” matrix, suggesting that this material was accreted as fine-grained rims around the high temperature components (also called matrix rims [10]). If this were correct, then only the matrix interstitial between these rimmed objects would be “true matrix”, i.e. water and organics bearing and with a bulk composition identical in all carbonaceous chondrite groups, close to that of CI chondrites and corre-

sponding to typical nebular dust + (organics-bearing) ice in relative proportions in weight  $\frac{3}{4}$  -  $\frac{1}{4}$ .

Based on the correlations displayed in Fig. 1, the composition of this “dirty” ice can be determined. Its atomic ratio  $\text{N/C}=0.045$  is consistent with macromolecular IOM associated with a few percent of extractable organic material. Assuming this composition for the organics yields 1/5 in weight of the icy material as organics and 4/5 as water. This may be more than the proportion of organics present in cometary ices, a likely consequence of heliocentric distance as icy grains within a few AU could have been partly vaporized (the organics being more refractory).

An interesting question is that of the relative distribution of the “true matrix” containing this ice and “matrix rims” within a given chondrite and across the carbonaceous chondrite groups. “True matrix” dominates in type 1 and 2 CI and CM chondrites whereas it is almost nonexistent in the type 3 (and above) CO, CV and CK chondrites. A possibility is that the “matrix rims” were accreted before the ice vaporized by the chondrule/CAI forming processes had recondensed whereas the interstitial “true matrix” was acquired later. Matrices of chondrule/CAI-rich chondrites would thus be mostly ice-free “rim-matrix” whereas matrices of chondrule/CAI-poor objects would be ice-bearing true matrix, which would have limited the amount of thermal metamorphism as suggested by [11].

**Conclusion:** Bulk chemical and oxygen isotopic compositions of carbonaceous chondrites show these to have inherited a common component as a host to  $\text{H}_2\text{O}$ , C and N. We suggest this common component to be ice accreted only within their interstitial “true matrix”.

#### References:

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